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The Effect of House Price Changes on Household Saving Behaviour
- A Theoretical and Empirical Study of the Dutch Case -*

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Abstract

This paper analyses the effect of changes in house prices on household saving. The life-cycle model predicts that homeowners compensate an unexpected decrease in home equity by increasing their saving, and that the effect becomes stronger as the age of the household increases. To test these hypotheses I use panel data from the Dutch Central Bank Household Survey (DHS) for the 2003-2013 period, which includes the boom and bust cycle of the Dutch housing bubble. I employ self-reported measures of the change in house prices, as well as a new measure of saving which allows to accurately separate active (dis)saving from capital gains and losses. In addition, I employ subjective house price expectations to compute measures of the unexpected change in house prices. The panel regression results show no significant effect of any of the measures of the change in house prices on saving, which suggests that households do not internalize the investment dimension of housing.

JEL Classification: D9, D11, D12, D14.
Keywords: House Prices; Saving; Life-Cycle, House Price Expectations; Subjective Expectations.

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1 Introduction

During the 1990s and early 2000s the Dutch housing market experienced continued increases in prices which came to an abrupt end in 2008, followed by a drop of around 20% between 2008 and 2013. Figure 1 shows a clear turning point in 2008, which coincided with a downturn in economic growth indicating the start of the recent economic crisis. A crucial factor determining the pre-2008 house price increase was the rise in housing demand, which was fuelled by pro-homeownership government measures implemented during the 1990s. The latter included generous tax deductions of mortgage interest payments and the introduction of a so-called national mortgage guarantee (NMG).[1] These measures, coupled with the relaxation of mortgage borrowing conditions, prompted a surge in homeownership and contributed to the development of a notable housing bubble, which busted in 2008.

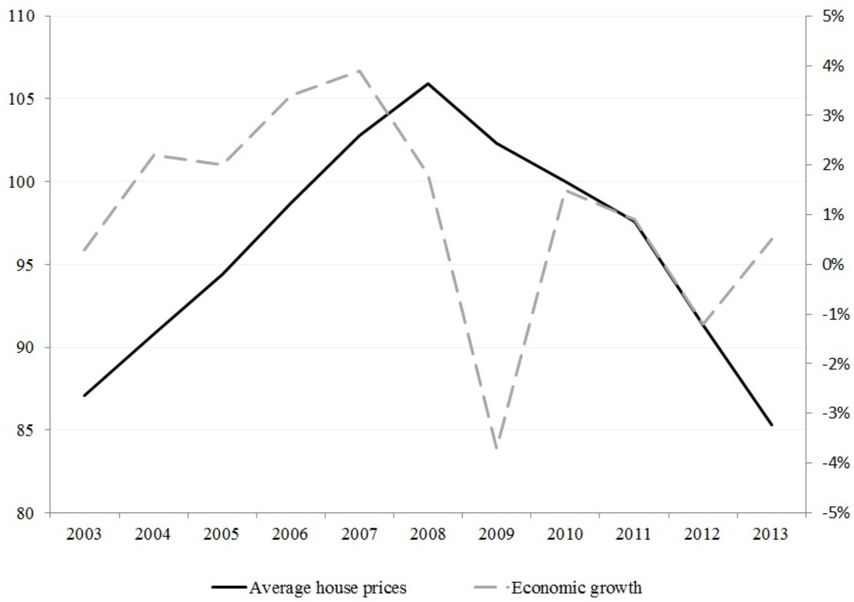

Figure 1 Evolution of House Prices and Economic Growth

Source: CBS; *Notes:* Average nominal house prices are given relative to 2010. The real rate of GDP growth, is given in terms of 2005 prices. The left axis measures house prices while the right axis measures economic growth.

In this paper I use the changes in house prices prompted by the 2008 turning point to study the consequences at the household level. When a household decides to purchase a house, it usually implies investing a big share of its wealth on a single and rather illiquid asset. Therefore, from the household perspective, housing is both a consumption good and an investment good. The aim of this paper is to investigate to what extent the investment dimension of housing is taken into account. To this end, I employ a life-cycle perspective and study how the saving behaviour of homeowners has reacted to the changes in house prices observed in Figure 1. According to the life-cycle model, if housing is regarded as a long-term investment, homeowners

[1]The NMG provides an insurance that applies if a homeowner, under certain unfavourable circumstance (*e.g.* unemployment, divorce or work incapacity) must sell his/her house and the proceedings do not cover the full remaining mortgage debt.

will offset house price increases (decreases) by decreasing (increasing) their saving. Therefore, if a negative relationship is observed, one may presume that housing is considered as a saving instrument, and thus that households take into account the investment dimension of housing. This is a very relevant question given the present context of increasing fragility of pension systems in Europe. Answering it, provides insights on whether housing wealth should be considered as savings when evaluating how households financially prepare for retirement.

In an early empirical study based on US data, Engelhardt (1996) finds that housing wealth changes negatively affect the saving of homeowners. This result suggests that housing is to some extent substitutable with other (more liquid) types of assets. Rouwendal and Alessie (2002) confirm this result using data from the Dutch socio-economic panel. More recently, van Beers *et al.* (2015) have revived the topic by employing Dutch administrative panel data. They find a negative effect of house prices on household saving, which appears to be strongest for young highly leveraged households. Several studies have looked at the other side of the coin, namely at the effect of house price changes on household consumption. Campbell and Cocco (2007) find a large positive effect on consumption for old homewoners and an effect that is close to zero for the younger ones. On the contrary, Attanasio *et al.* (2009) find that the relationship is stronger for younger than for old homeowners, while Disney *et al.* (2010) find no age heterogeneity. More recently, Browning *et al.* (2013), find no evidence of an effect of house price changes on consumption. Due to the variety in the results, it is difficult to establish a general relation at the micro level.[2] Therefore, every country and period deserves its own detailed analysis.

To conduct the present study, I start by exploring the topic at hand at the theoretical level. Following Artle and Varaiya (1978) and Li and Yao (2007), I include the housing asset into the life-cycle model. For the sake of simplicity, I do not consider neither lifetime uncertainty nor income uncertainty and I leave out the possibility of a bequest motive. The only source of uncertainty is thus the yearly rate of change in house prices. I do not endogenize the tenure decision (owning *vs* renting), and hence I study the case of a homeowner and of a renter separately.[3] The main prediction of the model is that households will react to an unexpected loss in housing wealth by saving more and thus increasing their stock of financial wealth. The intuition is that households increase saving to smooth the drop in consumption implied by the shock to lifetime income. In addition, the model predicts that the effect increases with age since older households have a shorter lifetime horizon and thus less time to smooth the shock.

To test the model implications I employ panel data mainly from the Dutch National Bank Household Survey (DHS) for the period 2003-2013 and I use a range of different measures of saving and house price changes. DHS provides a novel measure of saving by asking respondents how much money they have put aside in a given year. In previous literature (*i.e.* Engelhardt, 1996; Rouwendal and Alessie, 2002; and van Beers *et al.* 2015) saving is measured as the yearly change in wealth, which makes it difficult to disentangle active (dis)saving from capital gains (or

[2]Studies using aggregate data, *e.g.* Peek (1983), Bhatia (1987), Skinner (1989), Case *et al.* (2005) and Carroll *et al.* (2011), have consistently shown evidence of a positive link between house prices and consumption at the macro level. However, it seems difficult to account for all variables affecting aggregate consumption and house prices at the same time. Therefore, it is questionable to take a stand on a causal relationship between these two variables at the aggregate level (Attanasio *et al.* 2011).

[3]Note that these are the standard, and often implicit, assumptions in the micro literature on the effect of house price changes on saving and consumption. For the sake of transparency, I make them explicit in this paper so their relevance can be easily evaluated by the reader.

losses) and portfolio reshuffling. By measuring saving as self-reported money put aside by households in a given year, these problems are overcome. For the sake of robustness and comparison with previous literature, I employ a second measure of saving consisting of the yearly change in long-term assets.[4] Furthermore, since negative (positive) changes in mortgage debt can be considered as saving (dissaving), I employ a third measure of saving that consists of subtracting the yearly change in remaining mortgage debt from the the yearly change in long-term assets.

Regarding house price changes, DHS provides self-reported house prices and self-reported biennial changes in house prices. In addition, it provides subjective expectations on the evolution of house prices both at the level of the own house and at the market level. I use these subjective expectations to compute measures of the unexpected change in house prices. To do so, I subtract the expected change for a particular year from the self-reported change for that same year and, as a result, only the unexpected part of the change is left. This procedure is arguably more reliable than those employed in previous literature (*e.g.* Disney *et al.* 2010; Browning *et al.* 2013; and van Beers *et al.* 2015) based on the estimation of models of the aggregate house price process as a method to generate house price expectations, which are assumed to be homogeneous for all households. I addition to the house price change measures from DHS, I employ as well house price data from Statistic Netherlands (CBS) at the provincial level and data from the National Association of Real State Agents (NVM). The latter divide the Netherlands in 76 regions and provide yearly average house price values for each region.

By controlling for a series of demographic and economic variables, as well as for both unobserved household effects and aggregate time effects, the panel regression results show no significant effect of any of the measures of the change in house prices on saving. In most cases, the magnitude of the coefficient estimates I find, as well as the confidence intervals, are rather close to zero. The analysis does not yield significant results even when I condition the effect on age, on having negative home equity, on the sign of the house price change and on having an NMG. The results are in essence unchanged by a long series of robustness checks. Among others, the latter comprise the consideration of a lag between the change in house prices and the reaction in saving and a correction for possible measurement error caused by rounding error in self-reported house price changes. The latter check is conducted by using the CBS and NVM measures of the change in house prices (unaffected by rounding error) as an instrument for self-reported measures. These results suggest that households do not consciously use the housing asset as a saving instrument. Even though the purchase of a house usually implies *per se* investing a large share of household wealth into a single asset, the results imply that households regard housing more as a consumption good than as an investment good. In addition, they imply that Dutch households have taken a considerable loss in their wealth, since they have not compensated the recent drop in house prices with an increase in any other type of long-term assets. This has important implications in the present context of increasing fragility of the pension system.

The rest of the document is structured as follows: Section 2 presents the theoretical model; Section 3 provides data description and preliminary evidence; Section 4 explains the methodology; Section 5 presents the empirical results; Section 6 concludes. The appendices provide additional data description, summary statistics and an extended version of the theoretical model.

[4]By long-term assets I refer to assets that are meant as saving instruments for the long-term, like for instance private pension plans.

2 Life-Cycle Model With Housing

In this section I introduce a formal description of life-cycle saving and consumption in the presence of housing.[5] According to Engelhardt (1996), in the case of a homeowner, the effect of house price changes on saving crucially relies on four assumptions. First, the change must be unanticipated and perceived as permanent. Second, housing wealth must be substitutable with other more liquid forms of wealth. Third, households must be able to somehow liquidate housing wealth so it can actually be substituted by other forms of wealth. Fourth, the household must not regard the house as an asset to be bequeathed. Note that these assumptions are usually implicit in the literature. For the sake of transparency, I make them explicit here so their role can be easily assessed. Bearing the assumptions in mind, consider a household that lives for four periods and maximizes the following utility function

$$U(C_t^\tau, H) = \sum_{t=1}^{4} \frac{1}{(1+\rho)^{t-1}} \left(\frac{(C_t^\tau)^{1-\gamma}}{1-\gamma} + \theta \frac{(H(1+\lambda))^{1-\gamma}}{1-\gamma} \right), \tag{1}$$

where C_t^τ is consumption in period t as planned in period τ, H is constant housing, ρ is the rate of time preference, γ is the rate of relative risk aversion, θ is the preference for housing and λ is the utility gain from owning the occupied house.[6]

I assume the house is purchased by taking out a mortgage. In the Netherlands households can borrow close to 100% of the value of a house and hence there is no downpayment restriction. However, previous income is required, hence, the purchase of the house takes place at the beginning of the second period. Since there is no bequest motive, the house is sold at the beginning of the last period and the proceeds are used for consumption. Therefore, the household is a renter in the first and fourth periods. Bearing this in mind, the intertemporal budget constraint is given in the first period by

$$\mathit{\Omega} + E_1 \frac{\alpha_4 H(1-\phi)}{(1+r)^3} = \mathit{\Theta} + K_1 + E_1 \left(\frac{Mr^M}{(1+r)} + \frac{M(1+r^M)}{(1+r)^2} + \frac{K_4}{(1+r)^3} \right), \tag{2}$$

where $\mathit{\Theta}$ and $\mathit{\Omega}$ are lifetime consumption and lifetime labour income respectively, α_t is the unitary real price of housing, ϕ is the transaction cost incurred to sell the house, K_t is the cost of renting, M is the mortgage loan, r^M is the interest rate on the mortgage and r is the interest rate determining the return on savings.[7] The second term on the left hand side of (2) denotes the amount the household expects to receive when the house is sold, while the last term on the right had side accounts for the expected lifetime housing expenditures. The expectation operators are due to uncertainty regarding the rate of change in house prices, which, in turn, implies uncertainty in future house prices, mortgage payments and rental prices.[8] The rate of change in house prices is defined as $\mu_t = (\alpha_t - \alpha_{t-1})/\alpha_{t-1}$, and I assume the household expects

[5] I borrow modelling aspects from Artle and Varaiya (1978), Attanasio and Brugiavini (2003), Li and Yao (2007) and Campbell and Cocco (2007). For a more detailed description of the model which also considers the case of a renter, see Appendix E. Here I present only the case of a homeowner.

[6] $\lambda = 0$ for a renter and $\lambda \geq 0$ for an owner.

[7] I assume the rental price to be a function of the house price given by $K_t = \kappa + \delta\alpha_t H$, where κ is a constant and δ is the sensitivity to the house price. The household borrows 100% of the value of the house, hence $M = \alpha_2 H$.

[8] Note that I employ point expectations, implying that the expected future value of house prices affects the decision of the household while the variance (*i.e.* house price risk) does not.

it to be positive and constant, *i.e.* $E(\mu_t) = \mu > 0$.

At the beginning of period one the household sets an optimal plan by maximizing (1) subject to (2) which yields the closed form solution

$$C_t^1 = \frac{\Omega + E_1 \Xi}{\Lambda_t}, \tag{3}$$

where Λ_t is the factor containing ρ and r that distributes lifetime income among the four periods of life and Ξ is what I call the owning factor. The latter equals the value of the house at the selling period minus all the lifetime housing related expenses. Any change in the owning factor that is known in the planning period will be incorporated in the maximization problem and distributed among the four periods according to the Λ_t factors. If the expectation regarding μ_t is fulfilled in all periods, the house will be sold at the expected price an actual consumption in each period will equal the plan set in period one.

I consider now the event of a one period negative surprise in the value of μ_t that can take place in periods either two, three or four. I assume the information about the realized value of μ_t becomes available at the beginning of each period. In addition, I assume the negative surprise takes place only in a particular period, while in the rest of periods the initial expectation is fulfilled. Realized consumption in a period with a negative surprise is given by

$$C_t = C_t^1 + \eta_t, \tag{4}$$

where η_t is the forecast error equal to the difference between actual consumption, C_t, and the consumption plan set in period one, C_t^1. The forecast error occurs as a direct consequence of the lower-than-expected μ_t, which implies that the expected value of η_t is zero. Realized consumption is the result of the reoptimization the household undertakes when the new information is available. As can be seen in (4), a negative forecast error implies a reduction in consumption. The household realizes the house will be sold in the last period for a lower price compared to what was originally planned and adjusts consumption accordingly. For a given size of the shock, the contemporaneous effect on consumption will be higher the closer the household is to selling the house. If the surprise takes place in period two, there are still two more periods to smooth the shock, whereas if it happens in period four the whole shock to lifetime income has to be absorbed in just one period. Therefore, the contemporaneous effect on consumption will be stronger the older the household is.

The result for consumption in (4) can be easily given in terms of savings. The contemporaneous effect on the stock of savings of a change in house prices in periods two and three is given by

$$S_2 = S_1(1 + r) + Y_2 - C_2^1 - Mr^M - \eta_2 \tag{5}$$

and

$$S_3 = S_2(1 + r) + Y_3 - C_3^1 - M(1 + r^M) - \eta_3 \tag{6}$$

respectively, where S_t is the stock of savings (financial wealth) at the end of period t. The negative sign in front of the forecast error implies that a negative surprise in house prices has a positive effect on savings. The intuition is that households increase savings to smooth over

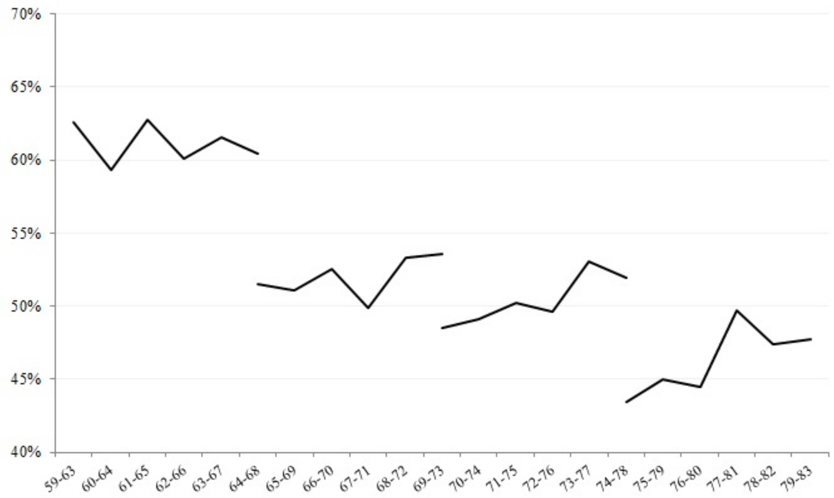

Figure 2 Evolution of Homeownership in Old Age

Source: DHS; *Notes:* Data between 2008 and 2013 are employed. Each one of the lines depicts a particular cohort. There are four five-year cohorts with ages 59-63, 64-68, 69-73 and 74-78 in 2009. The vertical axis measures cohort specific homeownership rate, while the horizontal axis measures age.

time the drop in consumption implied by the shock to lifetime income. The later in life, the less periods there are to smooth consumption so the higher has to be the compensatory increase in savings. Therefore, the contemporaneous effect on savings of a negative housing surprise is higher (in absolute value) the older the household is.

3 Data and Preliminary Evidence

To estimate the relations that derive from (5) and (6) I use data mainly from the Dutch National Bank Household Survey (DHS), which is an internet based panel survey that collects data on economic, financial and psychological aspects of both individual and household behaviour. It provides data for around two thousand Dutch households every year between 1993 and 2013. Households without a computer and/or access to internet are provided with a basic computer and internet connection to complete the survey. Attrition is dealt with by biannually refreshing the sample with new households to keep the panel representative of the Dutch population. Compensatory household weights are used to correct for unequal selection probabilities. To construct my sample I take only the responses from household heads and I exclude those households that have moved during the period of interest. The main advantage of this survey is that it provides measures of saving, assets, liabilities, house prices and house price expectations that are useful for the present study.[9] Since data on expectations are only available from 2003 onwards, I only use data for the years running from 2003 until 2013, both included, which is long enough to capture the boom and bust cycle in the Dutch housing market.

Following the model in Section 2, for the econometric analysis I split the sample between homewoners and renters. Figure 2 shows the cohort-specific relation between homeownership and age as found in the sample for households above 60 years of age. Even though there are obvious cohort effects, homwownership does not appear to decline clearly over time within co-

[9]For short variable definitions, sources and summary statistics, see tables A1 to A4 in Appendix A.

horts. This fact coincides with the evidence in Van der Schors *et al.* (2007) and in Van Ooijen *et al.* (2015), who also find steady homeownership rates among Dutch retirees despite strong cohort effects. In light of the evidence, the model assumption stating that homeowners sell their house towards the end of their life seems far fetched. However, the idea behind this assumption is not generating a realistic prediction, but more that of capturing the financial security that households obtain by possessing an asset that can eventually be sold later in life. Furthermore, it is possible that the elderly use other means to liquidate part of their housing like for instance by means of own-to-own transitions or by taking an extra mortgage.

3.1 Saving Measures

The main measure of saving I employ is obtained by asking DHS respondents how much money they have put aside in a given year. First, the questionnaire asks if any money was put aside. Those who respond affirmatively are then provided with seven intervals that range from "Less than 1500 Euros" to "More than 75000". This measure of saving is much less noisy and more accurate than other measures employed in the previous literature.[10] Nevertheless, it has the disadvantage of being provided in intervals and of not capturing dissaving. Figure 3 shows the yearly average responses, which I compute by taking the midpoint of each interval and by assigning the value 75000 to the highest interval. The solid columns shows a clear increase in average saving between 2005 and 2009. After 2009, there are yearly fluctuations but average values stay at a higher level compared to earlier years in the sample. The percentage of respondents reporting no money put aside stays rather constant over time at a value between 30% and 35%. These responses, to which I assign for now a value of zero, are excluded from the computation of the averages in Figure 3.

In addition to money put aside, and for the sake of comparison with the previous literature, I employ as well the yearly change in long-term assets (LTA) as a measure of saving. I define the latter as the sum of saving accounts, private pensions and employer sponsored saving plans.[11] The solid line in Figure 4 gives the evolution of the average yearly change in LTA, which appears to be more volatile than the measure depicted in Figure 3. Following Rouwendal and Alessie (2002) and van Beers *et al.* (2015), negative (positive) changes in remaining mortgage debt (RMD) can be considered as saving (dissaving). Therefore, I employ a third measure of saving which consists of subtracting the yearly change in RMD from the yearly change in LTA. Differently from van Beers *et al.* (2015), for households with a life-insurance mortgage, the DHS dataset allows considering the cash value of the life insurance as and additional part of the mortgage loan.[12] The time evolution of the latter measure's average is depicted by the dashed line in Figure 4, which shows even more volatility than the solid line. Note that when using this measures it is not possible to separate active saving from capital gains (or losses) and portfolio reshuffling. However, they have the advantage of capturing dissaving.

[10] Engelhardt (1996), Rouwendal and Alessie (2002) and van Beers (2015) employ changes in wealth components as a measure of saving. This measure is very noisy and it is very easily contaminated since it is difficult to disentangle active saving from capital gains and losses, as well as from portfolio reshuffling.

[11] Saving accounts include saving or deposit accounts, deposit books and savings certificates. For a thorough definition and classification of household financial assets in the Netherlands, see Alessie *et al.* (2002).

[12] Life-insurance mortgages are a popular type of mortgage in the Netherlands which couple the mortgage loan with the purchase of a life insurance.

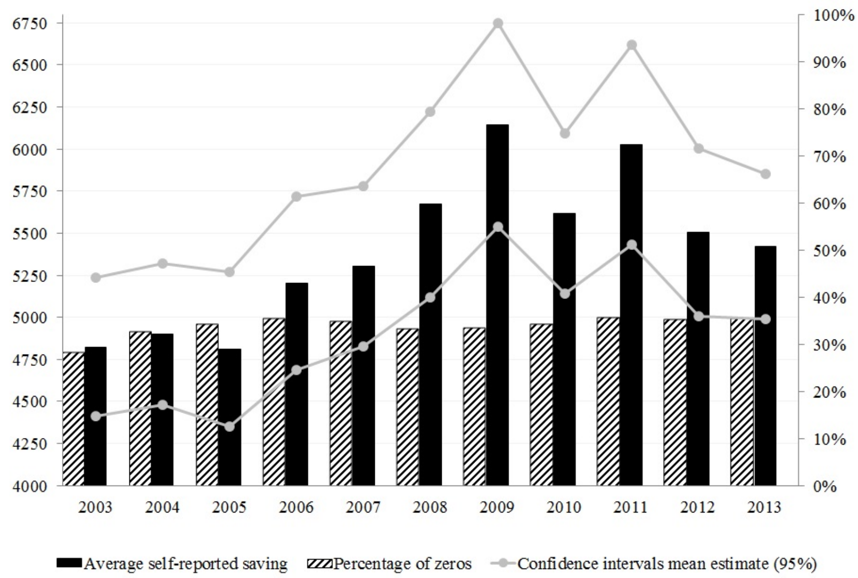

Figure 3 Average Saving (Money Put Aside)

Source: DHS; *Notes:* The survey question asks how much money the household has put aside in a given year. Respondents are provided with a series of intervals. Yearly averages are computed taking the midpoint of each interval. The stripped columns picture the percentage of households who report no money put aside, to whom a zero value is assigned. The zeros are not included in the average. The left axis measures saving, while the right axis measures the percentage of zeros.

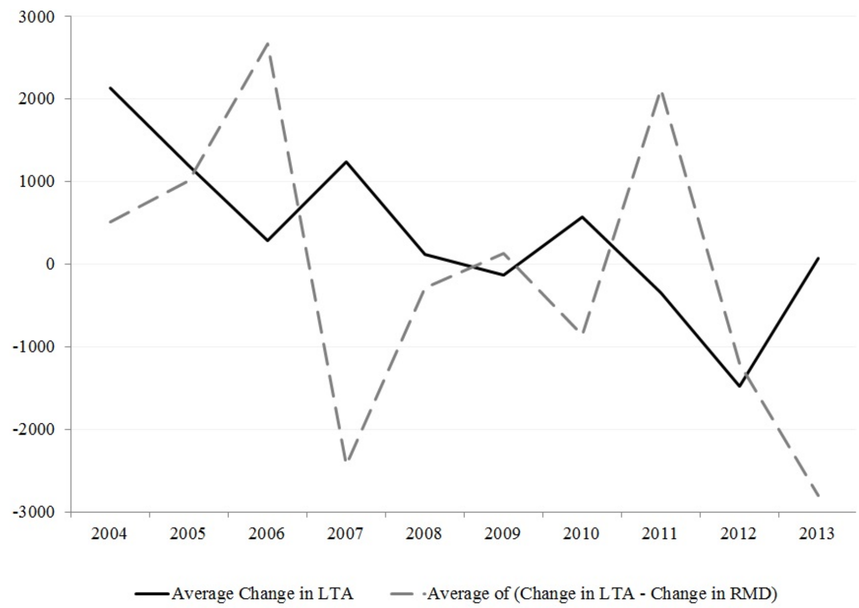

Figure 4 Average Saving (Change in Long-Term Assets)

Source: DHS; *Notes:* LTA stands for Long-Term Assets, while RMD stands for Remaining Mortgage Debt. Long-term assets are the sum of saving accounts, private pensions and employer sponsored saving plans.

3.2 House Price Change Measures

To capture the change in house prices I use different measures, as well as different sources. DHS provides self-reported house prices and self-reported biennial changes in house prices. The former are obtained by asking homeowners how much money they think they would get by selling their house, while the latter are obtained by asking about the percentage change in the house price for the two last years. I compute then two measures: the first, Self-reported 1, by taking the yearly percentage change in the self-reported house price; and the second, Self-reported 2, by transforming the two-year self-reported change into a yearly change. To obtain the latter, I assume that the percentage change in the last two years can be decomposed into two identical annual changes.[13] Ideally, the two measures should provide the same value. Figure 5 shows how on average they are very close (see dashed lines). In addition, both show a similar tendency over time compared to the national average provided by Statistic Netherlands (CBS) and depicted by the solid black line in Figure 5. The only remarkable difference is that the self-reported measures show a less pronounced decline between 2008 and 2013, which might have to do with the fact that homeowners are reluctant to acknowledge a decline in the price of their house.[14]

I complement the DHS self-reported measures with measures provided by CBS and by the National Association of Real State Agents (NVM). CBS provides average house price percentage changes at the province level (there are 12 provinces in the Netherlands), while NVM divides the Netherlands in 76 different regions and provides average percentage changes for each one of them. Both measures are based on all transactions taking place in the second hand housing market. With the aid of postal code information corresponding to all DHS respondents, I am able to place each household in a particular NVM region. In that way, I match DHS household data with NVM house price data. Figure 5 reports the national average of the CBS measure.

In addition to house price measures, DHS provides information on house price expectations. Homeowners are asked every year how much they expect the price of their house, as well as the average price in the market, is going to increase, in percentage, during the following year. Given this information, I compute measures of the unexpected change in house prices in the following way: for every year I subtract from the actual change in house prices (*i.e.* the self-reported measures, as well as the CBS and NVM measures) the change that was expected for that particular year. After the subtraction, only the unexpected part of the change is left. When the actual change is above the expected change, the household experiences a positive surprise, while a negative surprise occurs when the opposite takes place. Figures 5 and 6 show that, previous to the year 2008, homeowners in the sample experienced on average positive surprises since they expected lower changes in house prices compared to what actually happened. However, this situation reverses after the year 2010.

The availability of subjective expectations arguably provides a considerable advantage with

[13] If y_t is the given biennial change reported in year t, I compute the annual change corresponding to year t by the formula

$$x_t = \left[\sqrt{1+\frac{y_t}{100}}-1\right]100,$$

which transforms the biennial change into an annual change assuming the change is identical for the two years.

[14] van der Cruijsen *et al.* (2014) employ DHS data and find that homeowners hold an over-optimistic view of the price of their house.

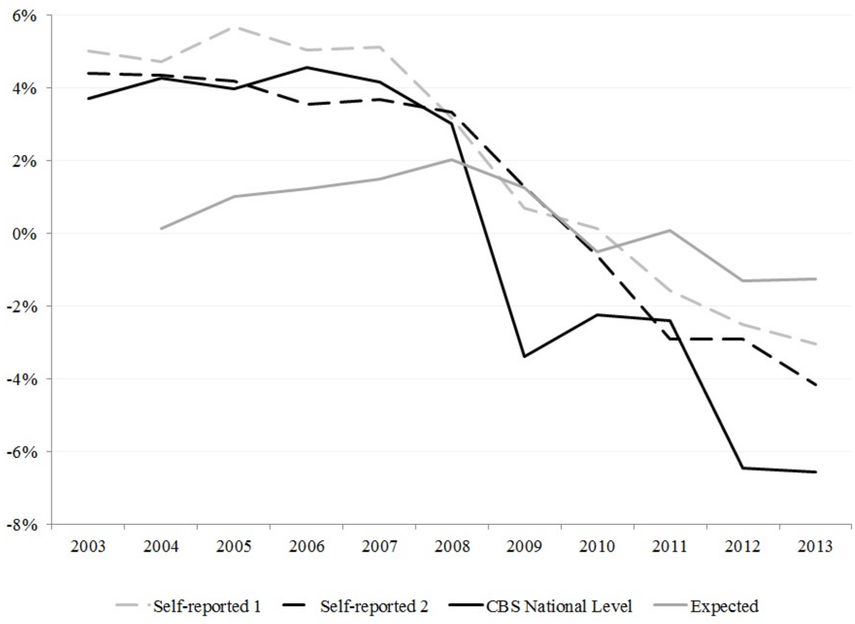

Figure 5 Expected vs Actual Average House Price Changes

Source: DHS and CBS; *Notes*: Self-reported 1 is the average change in the self-reported price of the own house. Self-reported 2 is the average self-reported change in the price of the own house. The expected change in house prices is measured at time t-1.

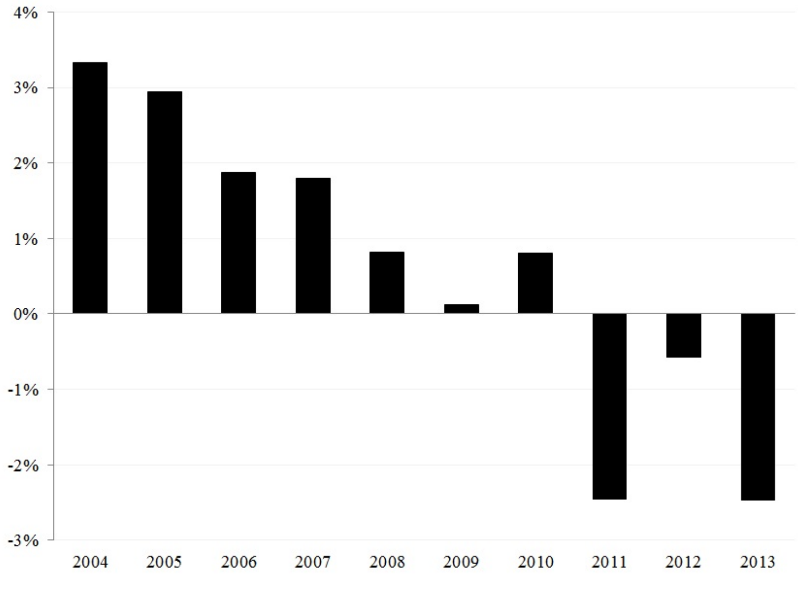

Figure 6 Average Unexpected Change in House Prices

Source: DHS; *Notes*: The unexpected change is computed here as the difference between Self-reported 2 for a particular year and the one-year expectation regarding the price of the own house for that same year. The average is taken once the subtraction is performed for each household in the sample.

respect to previous literature. For instance, Disney *et al.* (2010), Browning *et al.* (2013), and van Beers et al. (2015) rely on estimating models of the house price process to forecast future house price changes. They subtract the forecasted changes from the realized data and, thereby, come up with a proxy for unexpected changes. In contrariety to this approach, Niu and van Soest (2014) find that house price expectations depend on subjective perception and individual characteristics, thus they are highly heterogeneous. Their results are in line with previous literature (*e.g.* Case *et al.* 2012; and Beshears *et al.* 2013) and suggest that subjective data are a more reliable input when computing unexpected changes in house prices.

A comparison of Figures 3 and 4 with Figures 5 and 6 suggests a correlation between house price changes and household saving. Figure 3 suggests a negative correlation while Figure 4 suggests a positive correlation. Even though it is tempting to draw conclusions based on these figures, the evidence is very preliminary and it is only based on correlations between sample averages. It is likely that saving is conditioned by the business cycle, while the latter probably as well be related to the evolution of house prices. Therefore, it is necessary to disentangle the effect of house price changes from the effect of general macroeconomic conditions. In addition, there are several household level variables (income, risk aversion, family structure, etc.) that may influence saving as well as self-reported house price changes. Therefore, they have to be included in the microeconometric analysis.

4 Methodology

4.1 Specification

To estimate the effect of house price changes on saving I follow a reduced form method. From the theoretical model I derive an expression for savings, *i.e.* equations (5) and (6), which I use as a reference to set up a regression equation. I focus on Equation (6) since, besides mortgage interest payments, it includes the repayment of the principal and thus is more comprehensive. Moving lagged savings to the left of the equality and plugging in planned consumption, given by Equation (3), allows to rewrite (6) as

$$\mathit{\Delta} S_3 = S_2 r + Y_3 - \frac{\mathit{\Omega} + E_1 \Xi}{\mathit{\Lambda}_3} - M(1 + r^M) - \eta_3, \tag{7}$$

where $\mathit{\Delta} S_3 = S_3 - S_2$ is a flow variable indicating saving, *i.e.* the change in the stock of savings from one period to another. An unanticipated shift in the rate of change in house prices, μ_t, derives in a forecast error in the consumption level, η_t, which, as Equation (7) shows, has a negative effect on saving. To estimate this effect of an unanticipated change in house prices on saving, I set up the following linear regression equation

$$\mathit{\Delta} S_{it} = \beta_0 + \beta_1 HPC_{it} + \beta_2 (HPC_{it} X_{1it}) + \psi X_{1it} + \mathbf{X}'_{2it} \boldsymbol{\zeta} + D_t + c_i + \varepsilon_{it}, \tag{8}$$

where i and t are household and year indices respectively, the βs are unknown coefficients, $\mathit{\Delta} S_{it}$ denotes saving, HPC_{it} is the (unexpected) house price change given in percentages, X_{1it} is an interaction variable (*i.e.* either age, presence of a national mortgage guarantee, a dummy indicating negative house price changes or a dummy indicating negative housing equity), $\mathbf{X}_{2it}$ is a vector containing economic, demographic and psychological characteristics of the household (*i.e.* value of the house, household income, household wealth, education, mortgage expenditures, loan to value ratio, household structure and risk aversion) and ψ and $\boldsymbol{\zeta}$ are a coefficient and a vector of coefficients corresponding to the interaction and the control variables respectively. In addition, D_t is a time effect which I capture by introducing year dummies, and $c_i + \varepsilon_{it}$ is the composite error term, where c_i captures unobserved time-invariant household-specific effects and ε_{it} captures unobserved effects that vary across households and over time. I assume ε_{it} is independent over i and is normally distributed with mean zero.

Even though (8) does not have exactly the same form as (7), it provides an empirical strategy to estimate the relation between house price changes and saving that derives from (7). In the special case in which there are no interaction effects, *i.e.* by imposing the restriction $\beta_2 = 0$ in Equation (8), I am then interested in estimating β_1, which according to the model it is expected to have a negative sign. When considering interactions, the marginal effect of HPC_{it} on ΔS_{it} becomes

$$\frac{\partial \Delta S_{it}}{\partial HPC_{it}} = \beta_1 + \beta_2 X_{1it}, \tag{9}$$

which shows that it depends both on β_1 and β_2. Since all of the interaction variables that I introduce are coded as dummy variables, β_1 gives the marginal effect when the interaction dummy is zero, while the coefficient β_2 gives the additional effect for the subgroup indicated by the dummy X_{1it}. In this case the coefficients in (9) cannot be evaluated in isolation and hence I compute their joint significance. This issue becomes more clear when I present the results in Section 5.

4.2 Estimation

As explained in Section 3, the main measure of saving employed in this study is drawn from the DHS question on the yearly amount of money put aside by households. Respondents are given seven intervals that range from "Less than 1500 Euros" to "More than 75000", and they can also report that no money was put aside. A possibility to deal with such a variable consists of taking the midpoint of each interval and applying linear estimation methods. This option implies assigning a value of zero to the observations with no money put aside and a value of 75000 to the observations in the top interval. The problem is that those who are coded with a zero may have actually dissaved and those coded with 75000 may have actually saved more.

As an alternative to the linear approach, I apply interval regression estimation. As explained by Wooldridge (2010), this technique is the same as ordered probit but with known thresholds for the intervals. It consists of defining a new variable $int\_\Delta S_{it}$ that takes values ranging from one to seven corresponding to each one of the intervals, and that takes value zero if the respondent reports no money put aside, in which case saving is zero or negative. Relying on the normality of ε_{it}, the next step consists of defining a likelihood function that depends on the coefficients in (8) and that gives the probability that $int\_\Delta S_{it}$ takes any of the possible values from zero to seven.[15] Once the function is defined, maximum likelihood can be applied to estimate the

[15] In Appendix B, I provide the details explaining the derivation of the likelihood function. For additional information on interval estimation, see Wooldridge (2010).

coefficients. In contrast to binary probit, the resulting estimates are directly interpretable *as if* a continuous dependent variable had been observed.

An additional issue with methodological consequences is the high chance of a non-zero correlation between the unobserved household effect c_i and the explanatory variables, which would render the estimates inconsistent due to omitted variable bias.[16] Therefore, it is appropriate to consider a technique that tackles this issue. The usual candidate is the fixed effects estimator. However, it cannot be combined with maximum likelihood estimation due to so-called incidental parameter problem (Wooldridge, 2010). For this reason I employ a method proposed by Mundlak (1978), which assumes that c_i has the structure

$$c_i = \bar{\mathbf{X}}_i' \boldsymbol{\gamma} + u_i, \tag{10}$$

where $\bar{\mathbf{X}}_i$ is a vector containing the household-specific time averages of the regressors in Equation (8), $\boldsymbol{\gamma}$ is the corresponding vector of coefficients and u_i is a household-specific error component which is assumed to be uncorrelated with the regressors in (8). By plugging (10) into (8), the latter assumption allows to solve the inconsistency problem caused by the presence of c_i. Once the substitution is performed, the error term becomes $u_i + \varepsilon_{it}$ and I assume it to be uncorrelated with the regressors. However, due to the presence of u_i, the composite error will display within household serial correlation. Therefore, I combine the Mundlak method with cluster-robust estimation of the standard errors, which allows for both heteroskedasticity and autocorrelation (of unknown form) within households.

Due to the inclusion of the household-specific time averages of the explanatory variables in Equation (8), the estimation of the unknown coefficients will be only based on the variation that takes place within households. In fact, it can be proved that the Mundlak estimator is equivalent to the fixed effects estimator (a.k.a. the within estimator). However, the Mundlak estimator has the advantage that one can decide whether or not to include the time average of a certain variable in the vector $\bar{\mathbf{X}}_i$. For instance, I do not include in $\bar{\mathbf{X}}_i$ the time averages of the CBS and NVM variables since they are not likely to be correlated with c_i. For the same reason I do not include the average of the unexpected change in house prices. That is because when subtracting the expected change from the self-reported change, the effect of the household specific component cancels out since it is present in both variables. In addition, I do not include the average of the education variable since the variation that takes place within households is very low and mostly only due to measurement error.

Interval estimation can be applied in a panel data context, and it allows for the application of the above described Mundlak method. Therefore, the method I employ can be labelled as *interval regression with Mundlak terms*, where the latter refer to the household-specific time averages of the explanatory variables. When using the two secondary measures of saving as dependent variable, *i.e.* the change in long-term assets and the change in long-term assets minus the change in remaining mortgage debt, I simply apply linear regression with Mundlak terms since in that case there is no interval structure involved.

[16] In the results section I explain that indeed there is a significant correlation between c_i an the explanatory variables.

5 Results

This section presents the empirical results. First, I present the results obtained when using money put aside. After, I present the results obtained when using the change in long-term assets (LTA) and the change in LTA minus the change in remaining mortgage debt (RMD). In all regressions, the Mundlak terms are jointly significant at the 1% level, which implies a non-zero correlation between the household effect, c_i, and the regressors. Therefore, excluding the Mundlak terms would generate a problem of inconsistency. For each results table the estimation samples are set equal in number of observations to make the results comparable. In addition, for all measures of the change in house prices, as well as for both saving measures depicted in Figure 4, I drop both the top and bottom 1% observations to avoid the effect of extreme outliers.

5.1 Money Put Aside

Table 1 shows the results obtained for homeowners when employing different measures of the change in house prices without including any interaction variable. I employ the measures described in Section 3 and, in addition, I use the one-year expected percentage change in the price of the own house (Expected 1) and the one-year expected percentage change in the average market price (Expected 2). The coefficient β_1 can be interpreted as the change in saving (given in Euros) as a consequence of a one percentage point increase in house prices. All of the estimates of β_1 shown in Table 1 are not significantly different from zero. The point estimates range from -6.5 to 76.6. Both are, in absolute terms, less than 0.02% of the average money put aside in the sample. In fact, the bounds of the 95% confidence intervals are in all cases rather close to zero, which rules out the possibility of having an economically sizeable effect.[17]

In addition to the estimates of β_1, Table 1 shows a clear positive effect of income, implying a marginal propensity to save of about 8.7% out of an additional unit of income. I find as well a clear negative effect of the loan to value ratio, mortgage expenditures and house value.[18] Additionally, I find a positive effect, but less significant, of wealth and of higher education. On the other hand, I do not find a clear effect of variables such as age, number of children, risk aversion and presence of a partner. However, note that, due to the presence of the Mundlak terms, the estimates are based only on the variation that takes place within households.

Table 2 shows the results I obtain when using different measures of the unexpected change in house prices. Note that the model in Section 2 predicts that there will only be a contemporaneous effect if the change in house prices is not expected. To capture this phenomenon, I subtract the one-year expectation about the change in the price of the own house from the two self-reported measures of the house price change. In that way I obtain the variables Surprise 1 and Surprise 2. In addition, I subtract the same variable from the CBS and NVM variables to obtain Surprise 3 and 4, and I subtract the one-year expectation about the change in the

[17] Appendix C shows the point estimates in Tables 1 and 2 bonded by the 95% confidence intervals. Figure C1 shows how the values within the confidence intervals are all rather close to zero, except for the case in which the CBS data in house prices is used. In the latter case the estimate is less precise since the variation takes place only at the provincial level.

[18] Note that the coefficient on the house value variable is not the main coefficient of interest since it captures the effect a change in a stock (the value of the main residence) on a flow (saving), while β_1 captures the effect of a flow (house price changes) on a flow (saving).

Table 1 Money Put Aside: Interval Regression with Mundlak Terms (Homeowners)

	(1)	(2)	(3)	(4)	(5)	(6)
Income	87.772***	87.543***	87.539***	87.643***	87.738***	87.660***
	(18.421)	(18.447)	(18.434)	(18.451)	(18.424)	(18.396)
Wealth	6.151*	6.298*	6.176*	6.099*	6.151*	6.166*
	(3.422)	(3.406)	(3.405)	(3.421)	(3.399)	(3.404)
House value	-13.139**	-14.154***	-13.562***	-13.590***	-13.560***	-13.627***
	(5.389)	(4.842)	(4.707)	(4.712)	(4.722)	(4.735)
Mortgage exp.	-23.861***	-23.883***	-24.001***	-23.893***	-23.972***	-23.967***
	(5.936)	(5.933)	(5.908)	(5.966)	(5.888)	(5.908)
Ltv ratio	-17.678***	-17.472***	-17.497***	-17.262***	-17.152***	-17.395***
	(6.373)	(6.464)	(6.472)	(6.523)	(6.413)	(6.426)
Age	-118.346	-176.510	-119.798	-111.151	-99.651	-100.279
	(94.102)	(115.460)	(98.037)	(97.298)	(90.848)	(90.849)
Higher education	673.351*	721.297**	679.110*	679.182*	676.817*	669.651*
	(357.506)	(350.506)	(361.469)	(360.501)	(356.093)	(358.020)
N. of children	-81.120	-62.203	-71.968	-75.699	-83.139	-81.434
	(629.456)	(627.385)	(627.423)	(629.813)	(629.161)	(628.890)
N. of child out	208.393	219.934	209.170	208.829	212.044	208.374
	(217.749)	(218.345)	(217.867)	(218.515)	(217.485)	(217.162)
Partner	149.896	101.097	122.499	124.951	141.399	137.969
	(479.023)	(479.582)	(479.152)	(479.110)	(478.789)	(478.410)
Risk aversion	-4.768	-5.713	-2.818	-2.394	-4.582	-3.756
	(100.689)	(99.743)	(99.808)	(99.712)	(99.627)	(99.779)
Self-reported 1	-2.893					
	(9.691)					
Self-reported 2		46.914				
		(33.851)				
Expected 1			13.183			
			(44.446)			
Expected 2				34.065		
				(48.034)		
CBS provincial					76.666	
					(132.429)	
NVM regional						-6.538
						(33.984)
Constant	5874.363***	5090.886***	5891.383***	5917.438***	5683.262***	6055.380***
	(1466.773)	(1504.802)	(1483.249)	(1481.625)	(1519.079)	(1454.668)
Log Likelihood	-5961.985	-5958.186	-5961.633	-5961.612	-5962.116	-5962.309
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3726	3726	3726	3726	3726	3726
Households	1035	1035	1035	1035	1035	1035

Notes: Standard errors, clustered by household, are reported in parentheses. Dependent variable is money put aside in the last 12 months, including all the zero responses depicted in Figure 4. All monetary variables (income, wealth, house value and mortgage expenditures) are given in thousands of Euros. Time averages are included for all variables except for higher education, CBS provincial and NVM regional. *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. For variable definitions and summary statistics, refer to Tables A1 to A3 in Appendix A.

Table 2 Money Put Aside: Interval Regression with Mundlak Terms (Homeowners)

- Unexpected Change in House Prices -

	(1)	(2)	(3)	(4)	(5)	(6)
Income	95.912***	94.765***	95.409***	95.544***	95.419***	95.540***
	(20.389)	(20.386)	(20.401)	(20.375)	(20.364)	(20.345)
Wealth	3.482	3.485	3.516	3.532	3.509	3.535
	(3.307)	(3.295)	(3.293)	(3.295)	(3.297)	(3.295)
House value	-7.098	-9.955**	-9.174*	-9.267*	-9.131*	-9.190*
	(5.261)	(4.840)	(4.743)	(4.741)	(4.695)	(4.706)
Mortgage exp.	-22.525***	-22.768***	-22.906***	-22.871***	-22.953***	-22.958***
	(4.302)	(4.206)	(4.418)	(4.452)	(4.298)	(4.379)
Ltv ratio	-17.190***	-16.390**	-16.768**	-16.639**	-16.800**	-11.645**
	(6.566)	(6.668)	(6.621)	(6.638)	(6.600)	(6.628)
Age	-144.313	-144.748	-141.716	-141.708	-141.917	-141.924
	(106.992)	(107.103)	(107.050)	(107.035)	(107.139)	(107.023)
Higher education	788.554**	806.037**	787.499**	793.367**	786.824**	790.835**
	(379.066)	(375.308)	(380.233)	(382.146)	(379.300)	(380.485)
N. of children	114.360	98.713	122.333	121.492	121.211	119.613
	(629.971)	(627.231)	(627.491)	(628.526)	(628.471)	(628.907)
N. of child out	290.802	290.135	290.687	290.102	290.529	288.403
	(209.419)	(210.267)	(208.438)	(208.824)	(209.668)	(209.431)
Partner	382.595	403.437	402.329	395.748	403.928	396.257
	(514.433)	(514.149)	(515.438)	(515.137)	(516.147)	(515.723)
Risk aversion	-83.583	-75.784	-77.269	-79.211	-76.353	-77.382
	(101.501)	(101.381)	(100.250)	(100.618)	(100.657)	(100.828)
Surprise 1	-13.022					
	(10.827)					
Surprise 2		37.149				
		(44.427)				
Surprise 3			-6.249			
			(56.264)			
Surprise 4				-15.905		
				(35.363)		
Surprise 5					-0.826	
					(60.381)	
Surprise 6						-13.151
						(37.272)
Constant	5771.618***	5311.700***	5651.130***	5676.843***	5642.415***	5680.831***
	(1535.825)	(1512.449)	(1539.047)	(1534.812)	(1545.472)	(1536.550)
Log Likelihood	-5166.203	-5164.749	-5166.835	-5166.712	-5166.846	-5166.756
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3235	3235	3235	3235	3235	3235
Households	940	940	940	940	940	940

Notes: Standard errors, clustered by household, are reported in parentheses. Dependent variable is money put aside in the last 12 months, including all the zero responses depicted in Figure 4. All monetary variables (income, wealth, house value and mortgage expenditures) are given in thousands of Euros. Time averages are included for all variables except for higher education, Surprise 1 and Surprise 2. *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. For variable definitions and summary statistics, refer to Tables A1 to A3 in Appendix A.

average market price from the CBS and NVM variables to obtain Surprise 5 and 6. Similarly to Table 1, all of the β_1 estimates in Table 2 are not significantly different from zero.

A plausible explanation for the absence of an effect of the unexpected change in house prices lies on the fact that I am employing only very short-run expectations. One could argue that, since housing is a long-term investment, long run expectations are what matters and not just one-year expectations. DHS provides a possible solution to this issue by asking respondents what do they expect the yearly percentage change in house prices will be ten years ahead. Table A2 in Appendix A shows that the sample average of this variable is positive (3.34%) and larger than the average one-year expectation, suggesting that households expect house prices to recover somewhat in the longer term. However, if I use long-term expectations as provided by DHS as explanatory variable I still do not find a significant effect on money put aside by households.[19]

Even though I do not find a significant effect when using the whole sample of homeowners, it might be that there is actually an effect for particular groups of homeowners. In fact the model in Section 2 predicts that the effect will be stronger for older households *vis-à-vis* younger households. To test this hypothesis I generate three different age categories: less tan 35 (Age 1), between 35 and 65 (Age 2) and 65 or more (Age 3). Table 3 provides the results I obtain when interacting the Age 2 and Age 3 dummies (Age 1 is the reference category) with all the measures of the change in house prices in Tables 1 and 2. In this case, the estimate of β_1 captures the effect for the younger group, while the addition of β_1 and the corresponding interaction coefficient provides the estimate for the middle aged and older groups respectively. Table 3 shows that the estimates for all three age groups are not significantly different from zero. This result implies that not even the older homeowners display a significant reaction to the change in house prices.

In addition to the interaction effect of age, I check as well for the conditionality on having negative home equity and on having a National Mortgage Guarantee (NMG). Similarly to van

Table 3 Conditionality on Age

	Coefficient Estimate	*p*-value		Coefficient Estimate	*p*-value		Coefficient Estimate	*p*-value
Self-reported 1	-7.824	0.812	Self-reported 2	-25.975	0.718	Expected 1	65.442	0.466
Self-rep 1×Age2	9.012	0.994	Self-rep 2×Age2	111.263	0.112	Exp 1×Age2	-7.611	0.651
Self-rep 1×Age3	6.656		Self-rep 2×Age3	66.725		Exp 1×Age3	-48.811	
Expected 2	-62.781	0.610	CBS provincial	-27.281	0.746	NVM regional	40.075	0.545
Exp 2×Age2	134.004	0.450	CBS prov×Age2	79.979	0.331	NVM reg×Age2	-9.028	0.711
Exp 2×Age3	65.164		CBS prov×Age3	102.627		NVM reg×Age3	-28.865	
Surprise 1	3.236	0.917	Surprise 2	-4.300	0.964	Surprise 3	-67.561	0.524
Surprise 1×Age2	-8.615	0.933	Surprise 2×Age2	57.745	0.643	Surprise 3×Age2	5.317	0.542
Surprise 1×Age3	-9.579		Surprise 2×Age3	20.571		Surprise 3×Age3	16.936	
Surprise 4	14.702	0.837	Surprise 5	-153.895	0.208	Surprise 6	38.529	0.640
Surprise 4×Age2	-45.115	0.589	Surprise 5×Age2	88.632	0.352	Surprise 6×Age2	-58.887	0.214
Surprise 4×Age3	-57.491		Surprise 5×Age3	77.129		Surprise 6×Age3	-114.917	

Notes: Estimates are obtained by interval regression, with the same control variables and with the same samples as in Tables 1 and 2. Coefficient estimates for control variables are available on request. *p*-values of interaction effects are obtained by means of Wald tests of joint significance of the main effect and the of the interaction effects.

[19]For economy of space, the results are not reported here. They are available upon request.

Table 4 Conditionality on Negative Housing Equity

	Coefficient Estimate	p-value		Coefficient Estimate	p-value		Coefficient Estimate	p-value
Self-reported 1	-4.043	0.765	Self-reported 2	-40.944	0.306	Expected 1	-75.110	0.148
Self-rep 1×nhe	2.779	0.953	Self-rep 2×nhe	106.986	0.066	Exp 1×nhe	157.353	0.064
Expected 2	21.852	0.697	CBS provincial	27.431	0.576	NVM regional	16.490	0.654
Exp 2×nhe	10.260	0.813	CBS prov×nhe	-11.977	0.845	NVM reg×nhe	6.662	0.690
Surprise 1	6.326	0.610	Surprise 2	24.432	0.553	Surprise 3	9.375	0.855
Surprise 1×nhe	-14.937	0.576	Surprise 2×nhe	17.456	0.522	Surprise 3×nhe	-48.554	0.603
Surprise 4	-3.700	0.923	Surprise 5	-12.770	0.830	Surprise 6	-22.520	0.571
Surprise 4×nhe	-18.455	0.770	Surprise 5×nhe	-48.255	0.459	Surprise 6×nhe	-8.358	0.618

Notes: Estimates are obtained by interval regression, with the same control variables and with the same samples as in Tables 1 and 2. Coefficient estimates for control variables are available on request. p-values of interaction effects are obtained by means of Wald tests of joint significance of the main effect and the of the interaction effect.

Table 5 Conditionality on Having a National Mortgage Guarantee

	Coefficient Estimate	p-value		Coefficient Estimate	p-value		Coefficient Estimate	p-value
Self-reported 1	-11.261	0.398	Self-reported 2	43.864	0.300	Expected 1	32.054	0.580
Self-rep 1×nmg	13.763	0.716	Self-rep 2×nmg	-33.708	0.625	Exp 1×nmg	24.787	0.753
Expected 2	10.602	0.872	CBS provincial	-95.987	0.141	NVM regional	13.609	0.685
Exp 2×nmg	42.139	0.587	CBS prov×nmg	58.851	0.354	NVM reg×nmg	23.589	0.526
Surprise 1	-19.486	0.143	Surprise 2	43.160	0.348	Surprise 3	-78.146	0.146
Surprise 1×nmg	17.089	0.518	Surprise 2×nmg	-44.608	0.824	Surprise 3×nmg	-14.718	0.386
Surprise 4	-54.880	0.148	Surprise 5	-101.777	0.082	Surprise 6	-66.476	0.094
Surprise 4×nmg	11.364	0.437	Surprise 5×nmg	34.490	0.3573	Surprise 6×nmg	41.535	0.368

Notes: Estimates are obtained by interval regression. With the same control variables as in Tables 1 and 2 but with a sample of only homeowners with mortgage and with a house value below 250.000 Euros. Coefficient estimates for control variables are available on request. p-values of interaction effects are obtained by means of Wald tests of joint significance of the main effect and the of the interaction effect.

Table 6 Symmetry of the House Price Effect

	Coefficient Estimate	p-value		Coefficient Estimate	p-value		Coefficient Estimate	p-value
Self-reported 1	-9.939	0.420	Self-reported 2	39.325	0.292	Expected 1	14.542	0.831
Self-rep 1×neg	27.734	0.745	Self-rep 2×neg	-12.400	0.711	Exp 1×neg	-23.502	0.776
Expected 2	33.791	0.672	CBS Provincial	8.322	0.235	NVM regional	88.496	0.044
Exp 2×neg	-28.435	0.952	CBS Prov×neg	-15.004	0.478	NVM reg×neg	-90.455	0.232
Surprise 1	-16.547	0.181	Surprise 2	32.039	0.467	Surprise 3	-157.624	0.024
Surprise 1×neg	34.351	0.519	Surprise 2×neg	46.549	0.667	Surprise 3×neg	178.210	0.118
Surprise 4	20.801	0.642	Surprise 5	-87.653	0.271	Surprise 6	11.538	0.805
Surprise 4×neg	-25.147	0.345	Surprise 5×neg	-27.285	0.446	Surprise 6×neg	-51.772	0.481

Notes: Estimates are obtained by interval regression, with the same control variables and with the same samples as in Tables 1 and 2. Coefficient estimates for control variables are available on request. p-values of interaction effects are obtained by means of Wald tests of joint significance of the main effect and the of the interaction effect.

Beers *et al.* (2015) I define households with negative home equity, popularly known as households "under water", as those for whom the remaining mortgage loan exceeds the market price of their house. Households under water are financially strained and, in line with the previous literature, I expect them to display a stronger reaction to house price shocks compared to households with positive home equity. On the other hand, households with an NMG are entitled to receive financial help if they have to sell their house for a price below the remaining mortgage debt. In that way they are somewhat hedged against house price fluctuations, hence I expect them to be more indifferent to house price changes compared to households without an NMG. Tables 4 and 5 provide the results I obtain when interacting the different measures of my main explanatory variable with an under water dummy and an NMG dummy. The results show how the estimated effects for all these different subgroups in the sample are not significant as the p-values are always above or very close to 0.1.

There are several contributions in the literature (*e.g.* Engelhardt, 1996; Attanasio *et al.*, 2009; and van Beers *et al.*, 2015) which find that households respond asymmetrically to negative and positive changes in house prices. I perform a similar test by generating a dummy for negative changes and interacting it with the different measures of the change in house prices. For the present study, this experiment is almost the same as testing for a structural break around the years 2009 and 2010. That is because for all the house price change measures I employ there are clear turning points from positive to negative changes either in 2009 or 2010. Table 6 shows that, in this case as well, the estimates are not significantly different from zero. This implies that there is no asymmetry, simply because households do not react neither to positive nor to negative changes in house prices.

Finally, Table 7 provides the results I obtain when estimating the effect of house price changes on money put aside by renters. The specification I employ is very similar to that in Equation (8). The only difference is the exclusion of the homeowner-specific control variables (*i.e.* house value, mortgage expenditures and loan to value ratio) and the inclusion of the yearly total expenditures in rental payments. Columns 1 and 2 show that there is no significant effect of the CBS and NVM measures. Columns 3 and 4 show that there is no clearly significant effect not even for those renters who declare to be saving for the purchase of a house. In addition, the results in Table 7 show that renters have a lower propensity to save compared to homeowners, and that those who are saving for a house are indeed saving significantly much more than the rest of renters.

5.2 Change in LTA

The first columns in Tables 8 and 9 provide the results I obtain when using the yearly change in long-term assets (LTA) as a dependent variable. I define LTA as the sum of saving accounts, private pensions and employer sponsored savings plans. This measure has the problem that it does not distinguish between active and passive saving and, additionally, it might be affected by portfolio reshuffling. However, I use it for the sake of comparison with previous literature, as it is very close to the measures employed in Engelhardt (1996), Rouwendal and Alessie (2002) and van Beers *et al.* (2015). On the other hand, it has the advantage that it captures dissaving, while my main measure of saving, *i.e.* money put aside, does not.

Table 7 Money Put Aside: Interval Regression with Mundlak Terms (Renters)

	(1)	(2)	(3)	(4)
Income	54.071**	55.504**	46.253**	50.468**
	(22.839)	(22.819)	(23.206)	(23.403)
Wealth	-10.775	-10.463	-12.090	-11.531
	(17.080)	(16.839)	(17.393)	(17.099)
Rent	-0.013	-0.011	-0.013	-0.009
	(0.018)	(0.018)	(0.018)	(0.018)
Age	-73.626	-72.457	-92.441	-109.209
	(105.998)	(105.953)	(110.615)	(110.787)
Higher education	579.820	581.723	339.985	347.197
	(495.844)	(494.985)	(508.852)	(508.152)
N. of children	-1080.043*	-1064.902*	-1252.744**	-1227.914**
	(568.611)	(555.346)	(623.390)	(599.266)
N. of child out	-84.132	-55.544	-80.844	-46.292
	(188.171)	(182.897)	(188.690)	(183.396)
Partner	1921.398	1951.697	1673.142	1835.610
	(1761.933)	(1788.423)	(1865.559)	(1884.794)
Risk aversion	16.185	19.023	31.743	36.002
	(85.556)	(84.966)	(89.335)	(88.418)
Saving for a house			3347.606***	3181.857***
			(731.511)	(703.476)
CBS provincial	101.108		116.478	
	(177.030)		(183.059)	
NVM regional		-100.881		-104.453
		(147.417)		(147.382)
CBS prov. × saving for a h.			-105.184	
			(122.815)	
NVM reg. × saving for a h.				72.437
				(163.608)
Constant	877.842	155.020	-1158.798	-472.727
	1238.433	1613.01	(1687.782)	(1279.901)
Log Likelihood	-3084.230	-3082.372	-2976.203	-2974.674
Year dummies	Yes	Yes	Yes	Yes
Observations	2082	2082	2082	2082
Households	637	637	637	637

Notes: Standard errors, clustered by household, are reported in parentheses. Dependent variable is money put aside in the last 12 months, including all the zero responses depicted in Figure 4. All monetary variables, except for Rent, are given in thousands of Euros. Time averages are included for all variables except for Higher education, CBS provincial and NVM regional. *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. For variable definitions and summary statistics, refer to Tables A1 to A3 in Appendix A.

The first column in Table 8 shows that, when I do not consider any interaction effect, the estimates of β_1 based on the total change in house prices are all not significantly different from zero. Only when I use the NVM regional measure of the change in house prices I find an estimate with the expected sign and significant at the 10% level. However, this result is not robust across different measures of the change in house prices. Compared to Table 1, the estimates in Table 8 are less precise. The standard errors are higher and the 95% confidence intervals are wider. Therefore, it is less clear in this case whether the actual effect is close or not to zero, since there are rather high values (in absolute terms) that fall within the 95% confidence intervals. The first column in Table 9 shows that most of the measures of the unexpected change in house prices yield as well insignificant estimates. Only Surprise 4 yields a slightly significant estimate, which, once again, is not robust across the different measures I employ.

A concern related with the use of the change in LTA as a dependent variable is that the estimates on the control variables hardly make sense. For instance, there is no significant effect of income and the point estimates for the coefficient on the higher education dummy are negative. I find a very significant effect of the level of wealth, but this effect is clearly endogenous since LTA are part of total wealth and therefore there is an issue of reverse causality. The fact that there is not even a significant effect of income reveals that the dependent variable I employ here does not capture active saving accurately. I consider as well the interaction variables age, negative home equity, presence of NMG and sign of the house price change. However, the results do not add any substantial information since they do not yield any clearly significant results. In addition, I estimate the effect on the LTA of renters, which, as well, does not yield significant results.[20]

5.3 Change in LTA minus Change in RMD

Both Rouwendal and Alessie (2002) and van Beers *et al.* (2015) argue that negative (positive) changes in remaining mortgage debt (RMD) can be considered as saving (dissaving). Since mortgage debt is an important component in the portfolio of Dutch homeowners, I consider an additional measure of saving by subtracting the change in RMD from the change in LTA. This measure accounts for the fact that households may not increase their stock of savings as a consequence of the fall in house prices because they are deleveraging instead. If that is the case, this phenomenon should be captured by the measure of saving I employ here. When using this measure of savings, I include as additional explanatory variables a set of dummies indicating the type of mortgage held by the household. In this way, I account for the fact that some type of mortgages (*e.g.* interest only mortgages) do not allow for revisions of the monthly payments.

The second column of Table 8 shows that most of the measures of the change in house prices I employ yield coefficient estimates that are not significantly different from zero. Nevertheless, the first measure of the self-reported change in house prices yields a sizeable and slightly significant effect. In addition, the expected change in the average market price appears to have a statistically significant effect. This suggests that indeed households my draw down their mort-

[20]For economy of space, the results are not reported here. They are available upon request. The coefficient estimates corresponding to the control variables included in the regressions reported in Tables 8 are 9 are as well available upon request.

Table 8 Pooled OLS with Mundlak Terms (Homeowners)

	ΔLTA	Adjusted R^2	ΔLTA-ΔRMD	Adjusted R^2
Self-reported 1	-17.372	0.074	-289.469*	0.144
	30.052		150.692	
Self-reported 2	104.382	0.074	192.022	0.141
	119.499		266.787	
Expected 1	-227.795	0.075	453.246	0.142
	148.455		344.941	
Expected 2	-100.611	0.074	-765.873**	0.412
	136.094		385.977	
CBS provincial	9.395	0.074	1226.646	0.142
	263.531		803.911	
NVM regional	-183.470*	0.076	79.607	0.141
	103.593		249.366	
Year dummies	Yes	-	Yes	-
Observations	3718	-	3494	-
Households	1028	-	979	-

Notes: Standard errors, clustered by household, are reported in parentheses. ΔLTA stands for the change in long-term assets, while ΔRMD stands for the change in remaining mortgage debt. The same control variables as in Tables 1 and 2 are included in the estimation. Time averages are included for all variables except for Higher education, CBS provincial and NVM regional. *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. For variable definitions and summary statistics, refer to Tables A1 to A3 in Appendix A.

Table 9 Pooled OLS with Mundlak Terms (Homeowners)

- Unexpected Change in House Prices -

	ΔLTA	Adjusted R^2	ΔLTA-ΔRMD	Adjusted R^2
Surprise 1	-26.132	0.064	-192.736	0.153
	25.449		120.501	
Surprise 2	42.904	0.063	15.984	0.152
	73.324		157.326	
Surprise 3	-68.049	0.063	138.907	0.151
	89.779		202.787	
Surprise 4	-151.291*	0.064	-103.652	0.152
	84.688		163.260	
Surprise 5	-19.741	0.063	288.894	0.152
	81.067		233.925	
Surprise 6	-151.525	0.064	0.944	0.152
	109.059		181.056	
Year dummies	Yes	-	Yes	-
Observations	3227	-	3052	-
Households	939	-	896	-

Notes: Standard errors, clustered by household, are reported in parentheses. ΔLTA stands for the change in long-term assets, while ΔRMD stands for the change in remaining mortgage debt. The same control variables as in Tables 1 and 2 are included in the estimation. Time averages are included for all variables except for Higher education, Surprise 1 and Surprise 2. *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level. For variable definitions and summary statistics, refer to Tables A1 to A3 in Appendix A.

gage debt when house prices decrease. However, a word of caution is pertinent since, once again, these results are not robust to most of the measures of the change in house prices that I employ. In addition, they are not confirmed by the analysis based on the unexpected change in house prices, which, as shown in the second column of Table 9, yields only insignificant estimates.

Regarding the control variables, this last measure of saving yields slightly more sensible results compared to the raw change in LTA. I find again a significant, and large in magnitude, effect of income and I find as well a slightly significant negative effect of age. I find a very strong and significant effect of the loan to value ratio, but most likely this is due, once again, to an issue of reverse causality since changes in RMD have a direct impact on this variable. Once more, I estimate the effect of the change in house prices taking into account all of the previously considered interaction effects, and, as well, I estimate the effect for renters. However, the analyses do not yield any clearly significant results. [21]

5.4 Robustness Checks

5.4.1 Long Run *vs* Short Run

A plausible explanation for the results I obtain is that individuals do not react to house price changes because they expect them to increase again in the future. Therefore, only those who are planning to sell the house in the short run are truly surprised by the recent decline in house prices. DHS offers a possibility to check for this by asking homeowners whether they are searching for a new accommodation, which could imply looking for another bought accommodation, for a rental house or for a nursing home. Table A2 in Appendix A shows that 6% of homeowners in the sample reply affirmatively to this question. Assuming that looking for a new location goes together with selling the current one, this group of homeowners becomes particularly sensitive to recent changes in house prices. To check for this I create a dummy that takes value 1 if a homeowner is looking for a new accommodation and 0 otherwise. Interacting this dummy with the different measures of the change in house prices yields no significant effect for this particular group of homeowners. This implies that a change in house prices does not derive into a saving increase not even when a household is willing to sell the house in the short run.[22]

5.4.2 Measurement Error

There is a branch the literature that points at the measurement error caused by the tendency of survey respondents to round their answers up or down to a specific number (de Bresser and van Soest, 2013). The histograms in Appendix D show a clear tendency to round towards particular values in some of the measures of the change in house prices I use. More in particular, respondents round their answers when reporting the price of their house, the change in the price of their house in the last two years, and the expected future change in the price of their house and the average price in the market. According to de Bresser and van Soest (2013), it is reasonable to assume that rounding is correlated with particular characteristics of individuals such as age, education, risk aversion and other usually unobserved attributes. Therefore, this is a case of

[21] For economy of space, the results are not reported here. They are available upon request.

[22] Results of this and all robustness checks described in this section are available upon request.

a non-classical measurement error and it is not clear whether it implies the usual attenuation bias.[23] To address this problem, I use the CBS and NVM measures of the change in house prices, which I assume to be uncorrelated with rounding, as instruments for Self-reported 1, Self-reported 2, Surprise 1 and Surprise 2, and estimate β_1 by means of two-stage least squares. Even though less precise, the resulting estimates are still not significantly different from zero.

5.4.3 Lagged Effect

An additional plausible explanation for the results has to do with the timing of the effect. It can be that homeowners do not react immediately to changes in house prices. Instead, it can be that it takes some time before they realize that the main residence has experienced a relevant price change. To check for this, I lag the different measures of the change in house prices for one and two years. Lagging the total change in house prices one and two periods yields no evidence of a significant effect. Therefore, the results of the analysis of the contemporaneous effect are confirmed by the analysis of the lagged effect.

5.4.4 Sample Selection

Finally, note that for each set of regressions in each results table provided in this section the same observations where used. This implies dropping a few observations when performing some of the regressions. Generally this implies only dropping very few of them. However, in some cases the number of observations dropped is substantial. For instance, in the sixth column of Table 1 more than 2000 observations were dropped to equalize the number of observations across columns. Additionally, as mentioned in Section 3, for all measures of saving (except for money put aside) and of the change in house prices I drop the top and bottom 1% of observation in the distribution to avoid the effect of extreme outliers. To check whether dropping observations for both reasons has an effect on the results due to sample selection, I rerun all of the regressions including all observations that were dropped in the main analysis. The results still show no significant effect of house price changes on household saving.

6 Conclusions

In this paper I have studied the effect of recent changes in house prices on the saving of Dutch homeowmers and renters. The version of the life-cycle model that I develop predicts that households will offset unexpected negative changes in house prices by increasing their stock of savings. In addition, it predicts that the effect will be stronger the older the household is. I test these hypotheses by employing a whole range of measures of saving and of house price changes which I draw mainly from the Dutch National Bank Household Survey (DHS), but also from Statistics Netherlands (CBS) and from the National Association of Real State Agents (NVM). This paper contributes to the literature in several ways. First, I employ a new measure of saving which allegedly captures active saving more accurately compared to previous literature; second, I exploit the recent sharp price drop in the Dutch housing market; and third, I apply new measures of

[23] In Appendix D I provide a derivation of the bias caused by the measurement error problem. The sign of the bias will depend on the correlation between the rounding behaviour and the explanatory variables.

the unexpected change in house prices based on subjective expectations reported by households.

By controlling for a series of demographic and economic variables, as well as for both unobserved household effects and aggregate time effects, the panel regression results show no clearly significant effect of any of the measures of the change in house prices on saving. This result holds when I condition the effect on age, on having negative home equity, on having a national mortgage guarantee (NMG) and on the sign of the house price change. This finding is in contrast with most of the existing literature which finds an effect of house prices on either saving or consumption. However, my results are in line with Browning *et al.* (2013), and partially with van Beers *et al.* (2015) since the latter reject the life-cycle hypothesis, which predicts that the effect will be stronger for older households.

The main conclusion I extract from my results is that Dutch households do not behave as the life-cycle model predicts when it comes to housing, *i.e.* they do not view the housing asset as a saving instrument and, accordingly, they do not offset house price decreases by increasing saving. This implies that individuals do not internalize the investment dimension of housing, and thus they do not consciously plan to use the house as a mean to complement their income during retirement. Additionally, it implies that Dutch households have recently taken a considerable loss in their wealth, since the decline in house prices has not been compensated by increasing the ownership of other long-term assets. Understanding this and other facts about how individuals plan to finance their retirement is of capital importance in the present context of increasing fragility of pension systems in Europe.

A venue for further research is to study whether households actually do use housing equity to finance any kind of expenditures during retirement. Even though this paper reveals they do not plan to do it, whether they actually do it or not is as well an interesting question. A caveat for public policy makers is that the use of housing equity as an additional source of income during retirement should be encouraged. Especially given the current uncertainty about the sustainability of the pension system and of the public coverage of long-term healthcare expenditures.

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Appendix A: Additional Tables

Table A1 Variable Definitions and Sources

Variable	Definition	Source
Savings Measures		
Money put aside	Money in Euros put aside in the past 12 months.	DHS
ΔLTA	Yearly change in long-term assets (saving accounts, private pension and employer sponsored saving plans) in Euros.	DHS
ΔLTA - ΔRMD	Yearly change in long-term assets minus yearly change in remaining mortgage debt in Euros.	DHS
House Price Change Measures		
Self-reported 1	Yearly percentage change in the self-reported house price with respect to the previous year.	DHS
Self-reported 2	Reported yearly percentage change in the house price with respect to the previous year.	DHS
Expected 1	Expected percentage change in the house price for the next year with respect to the present year.	DHS
Expected 2	Expected percentage change in average house market prices for the next year with respect to the present year.	DHS
Longexp	Expected yearly percentage change in average house prices in ten years.	DHS
CBS provincial	Average percentage change in house market prices at the province level.	CBS
NVM regional	Average percentage change in house market prices at the NVM region level.	NVM
Surprise 1	Self-reported 1 minus lagged Expected 1.	DHS
Surprise 2	Self-reported 2 minus lagged Expected 1.	DHS
Surprise 3	CBS provincial minus lagged Expected 1.	DHS and CBS
Surprise 4	NVM regional minus lagged Expected 1.	NVM and CBS
Surprise 5	CBS provincial minus lagged Expected 2.	DHS and CBS
Surprise 6	NVM regional minus lagged Expected 2.	NVM and CBS

Table A1 Variable Definitions and Sources (continuation)

Variable	Definition	Source
Control Variables		
Income	Yearly total net income of the household in Euros.	DHS
Weatlh	Net wealth in thousands of Euros (main residence and mortgage excluded).	DHS
House value	Amount in thousands of Euros the household expects to get for the first residence if it was sold.	DHS
Mortgage exp.	Yearly amount in thousands of Euros of mortgage related expenditure (first residence).	DHS
Age 1; Age 2; Age 3	Dummies indicating age of the household head. Age 1: 35 or younger, Age 2: between 35 and 65, Age 3: above 65.	DHS
Higher education	Dummy indicating higher education.	DHS
N. of children	Number of children living in the household.	DHS
N. of child. out	Number of children living outside of the household.	DHS
Partner	Dummy indicating the presence of a partner.	DHS
Risk aversion	Index variable indicating how much household heads agree with having save investments with guaranteed returns, 1: totally disagree, 7: totally agree.	DHS
NMG	Dummy indicating the presence of a national mortgage guarantee	DHS
Ltv ratio	Remaining mortgage plus cash value life insurance, all divided by market price of residence. Result is multiplied by by a hundred so as to be given in percentages.	DHS DHS
NHE	Dummy indicating the presence of negative home equity.	DHS
Rent	Yearly amount spent in Euros in renting the main residence.	DHS
Saving for a house	Dummy indicating whether a renter is saving to buy a house.	DHS
Looking for a house	Dummy indicating whether a homeowner is looking for a new accommodation.	DHS

Notes: DHS stands for Dutch National Bank Household Survey. NVM and CBS are the Dutch acronyms for the National Association of Real State Agents and Statistics Netherlands respectively.

Table A2 Summary Statistics (Homeowners)

Variable	Mean	Median	Std. Dev.	W. Std. Dev.	Min.	Max.
Money put aside	4686.728	3250	6597.160	4444.694	0	75000
ΔLTA	765.934	0	19396.230	17209.870	-107125	107883.400
ΔLTA - ΔRMD	415.542	0	47888.370	40199.790	-259564.700	285000
Income	35.861	31	14.216	6.937	12	75
Wealth	61.984	33.592	80.379	34.552	-49.447	486.662
House value	275.713	250	110.914	27.537	0	695
Mortgage expenditure	4.880	3.984	5.356	2.535	0	48.024
Ltv ratio	36.130	28.779	35.073	13.135	0	197.927
Age 1 (0-35)	0.068	-	-	-	-	-
Age 2 (35-65)	0.633	-	-	-	-	-
Age 3 (65+)	0.298	-	-	-	-	-
Higher education	0.475	-	-	-	-	-
Number of children	0.619	0	1.038	0.245	0	6
Number of child. out	1.185	1	1.396	0.488	0	8
Partner	0.795	-	-	-	-	-
Risk aversion	5.233	6	1.659	0.961	1	7
NMG	0.304	-	-	-	-	-
NHE	0.067	-	-	-	-	-
Looking for a house	0.059	-	-	-	-	-
Self-reported 1	1.238	0	12.492	10.641	-57.142	96.319
Self-reported 2	0.567	0	4.503	3.350	-10.555	22.500
Expected 1	-0.082	0	3.188	2.361	-10	15
Expected 2	-0.317	0	3.262	2.486	-12	15
Longexp	3.342	2	4.450	3.509	-40	90
CBS provincial	-0.245	-1.283	4.440	3.396	-7.306	7.740
NVM regional	-0.230	0.407	5.242	4.474	-19.337	12.585
Surprise 1	1.246	0	12.200	10.283	-57.142	81
Surprise 2	0.576	0	4.366	3.469	-13.555	22.500
Surprise 3	-0.231	-0.596	4.531	3.428	-14.281	14.588
Surprise 4	-0.169	0.296	5.567	4.709	-14.682	14.926
Surprise 5	-0.508	-1.055	4.396	3.395	-13.219	14.809
Surprise 6	-0.373	-0.325	5.735	4.923	-14.682	14.926

Notes: Money put aside and Income are coded in intervals. In both cases I take the midpoint of each interval to compute summary statistics. All monetary variables (except the saving measures) are given in thousands of Euros. For all variables the sample employed is the estimation sample in Table 1, *i.e.* number of observations is always 3726. W. Std. Dev. stands for Within Standard Deviation.

Table A3 Summary Statistics (Renters)

Variable	Mean	Median	Std. Dev.	W. Std. Dev.	Min.	Max.
Money put aside	2320.845	750	4824.294	3143.431	0	75000
ΔLTA	457.861	0	13599.710	11892.06	-106000	109000
Income	24.463	18000	11.423	5.097	12	75
Wealth	23.030	7.989	43.369	20.046	-50.487	374.925
Age 1 (0-35)	0.109	-	-	-	-	-
Age 2 (35-65)	0.558	-	-	-	-	-
Age 3 (65+)	0.331	-	-	-	-	-
Higher education	0.307	-	-	-	-	-
Number of children	0.268	0	0.679	0.156	0	4
Number of child. out	1.012	0	1.415	0.451	0	12
Partner	0.433	-	-	-	-	-
Risk aversion	4.902	6	2.009	1.246	1	7
Rent	536.191	453	1451.533	1248.182	0	44388
Saving for a house	0.083	-	-	-	-	-
CBS provincial	-0.0721	0.468	4.564	3.307	-7.306	7.740
NVM regional	0.059	0.785	5.018	4.143	-18.404	12.585

Notes: Money put aside and Income are coded in intervals. In both cases I take the midpoint of each interval to compute summary statistics. All monetary variables (except for the saving measures and for Rent) are given in thousands of Euros. For all variables the sample employed is the estimation sample in Table 7, *i.e.* number of observations is always 2082. With. W. Std. Dev. stands for Within Standard Deviation.

Appendix B: Derivation of the Likelihood Function

The derivation of the likelihood function can be best explained by considering the dependent variable in Equation (8), ΔS_{it}, as an underlying latent variable that is not observed. Instead, I observe an ordinal variable $int\_\Delta S_{it}$ that takes values from zero to seven indicating each one of the different intervals for the latent variable. Table B1 shows the exact correspondence between the values of $int\_\Delta S_{it}$ and the intervals for ΔS_{it}.

Table B1 ΔS_{it} Intervals

0	$(-\infty, 0]$
1	(0, 1500]
2	(1500, 5000]
3	(5000, 12500]
4	(12500, 20000]
5	(20000, 37500]
6	(37500, 75000]
7	$(75000, +\infty)$

Plugging (10) into (8) and rewriting it as

$$\Delta S_{it} = \mathbf{Z}'_{it}\boldsymbol{\xi} + \varepsilon_{it},$$

where $\mathbf{Z}_{it}$ is a vector with a column for each variable in the model and $\boldsymbol{\xi}$ is the corresponding parameter vector, and taking into account the assumption that ε_{it} follows a normal distribution with a zero average, I can write the probability that $int\_\Delta S_{it} = 0$ conditional on $\mathbf{Z}_{it}$ as

$$\begin{aligned} P\{int\_\Delta S_{it} = 0|\mathbf{Z}_{it}\} &= P\{\Delta S_{it} \leq 0|\mathbf{Z}_{it}\} \\ &= P\{\varepsilon_{it} \leq -\mathbf{Z}'_{it}\boldsymbol{\xi}|\mathbf{Z}_{it}\} \\ &= \Phi\left(-\frac{\mathbf{Z}'_{it}\boldsymbol{\xi}}{\sigma}\right), \end{aligned}$$

where Φ is the cumulative distribution function corresponding to a normal, and $\sigma = \sqrt{Var(\varepsilon_{it})}$. Similarly, the probability that ΔS_{it} falls within a bounded interval, *e.g.* interval 1, can be written as

$$\begin{aligned} P\{int\_\Delta S_{it} = 1|\mathbf{Z}_{it}\} &= P\{0 < \Delta S_{it} \leq 1500|\mathbf{Z}_{it}\} \\ &= P\{-\mathbf{Z}'_{it}\boldsymbol{\xi} < \varepsilon_{it} \leq 1500 - \mathbf{Z}'_{it}\boldsymbol{\xi}|\mathbf{Z}_{it}\} \\ &= \Phi\left(\frac{1500 - \mathbf{Z}'_{it}\boldsymbol{\xi}}{\sigma}\right) - \Phi\left(-\frac{\mathbf{Z}'_{it}\boldsymbol{\xi}}{\sigma}\right). \end{aligned}$$

Given the above probabilities, the log likelihood function can be written as

$$
\begin{aligned}
\ln L = & \sum_{i=1}^{N}\sum_{t=1}^{T_i} w_0 \log\Phi\left(-\frac{\mathbf{Z}'_{it}\boldsymbol{\xi}}{\sigma}\right) \\
& + \sum_{k=1}^{6}\left[\sum_{i=1}^{N}\sum_{t=1}^{T_i} w_k \log\left\{\Phi\left(\frac{int_{uk}-\mathbf{Z}'_{it}\boldsymbol{\xi}}{\sigma}\right)-\Phi\left(\frac{int_{lk}-\mathbf{Z}'_{it}\boldsymbol{\xi}}{\sigma}\right)\right\}\right] \\
& + \sum_{i=1}^{N}\sum_{t=1}^{T_i} w_7 \log\left\{1-\Phi\left(\frac{75000-\mathbf{Z}'_{it}\boldsymbol{\xi}}{\sigma}\right)\right\},
\end{aligned}
$$

where N is the total number of households observed, T_i is the number of periods a particular household i is observed, w_k is a dummy indicating whether an observation falls within the interval k, and int_{uk} and $int_l k$ are the upper and lower bounds of the interval k respectively. The first summation term in the log likelihood indicates the probability that saving is zero or negative. The second term indicates the probability that saving falls within a particular bounded interval, while the latter term indicates the probability that saving is above 75000 Euro.

Appendix C: Confidence Intervals

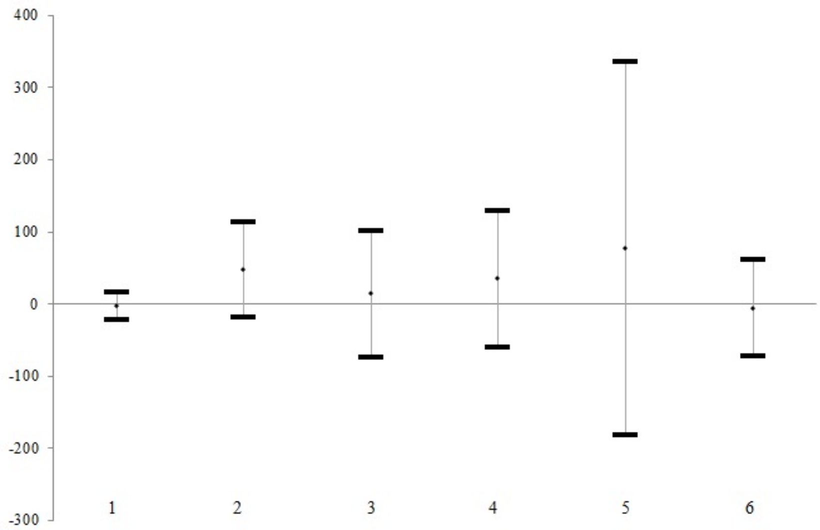

Figure C1 Confidence Intervals Results Table 1

Source: DHS; *Notes:* The data points, from 1 to 6, correspond with the point estimates of β_1 in columns 1 to 6 of Table 1. The point estimates are surrounded by the 95% confidence intervals.

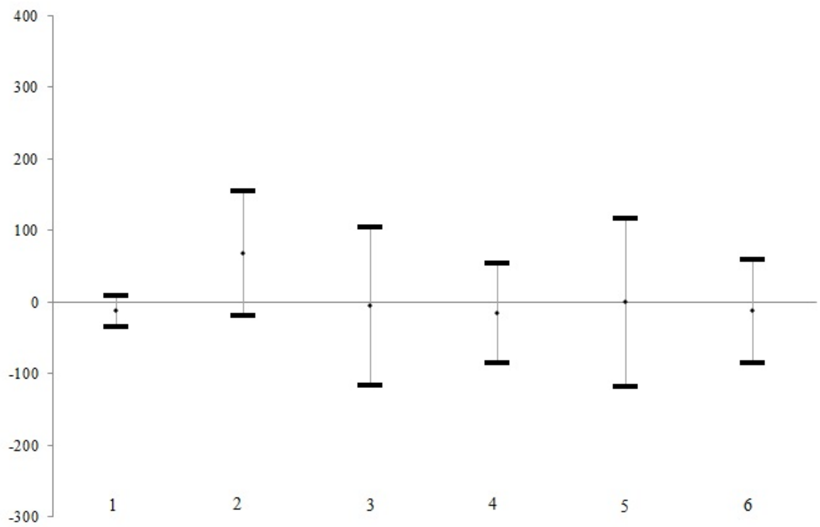

Figure C2 Confidence Intervals Results Table 2

Source: DHS; *Notes:* The data points, from 1 to 6, correspond with the point estimates of β_1 in columns 1 to 6 of Table 2. The point estimates are surrounded by the 95% confidence intervals.

Appendix D: Measurement Error

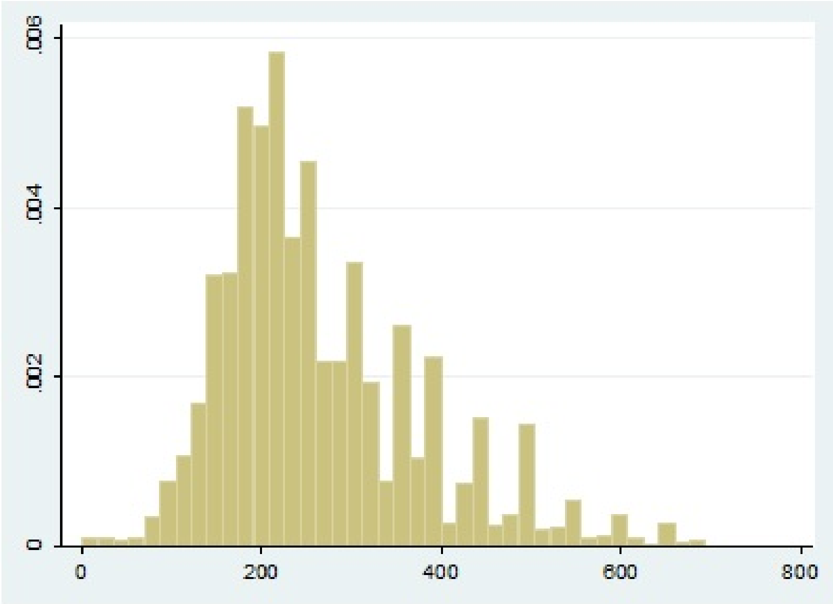

Figure D1 Self-Reported House Price

Source: DHS; *Notes:* The horizontal axis indicates the self-reported house price, while the vertical axis denotes the density. Renters are excluded from the histogram. House prices are given in thousands.

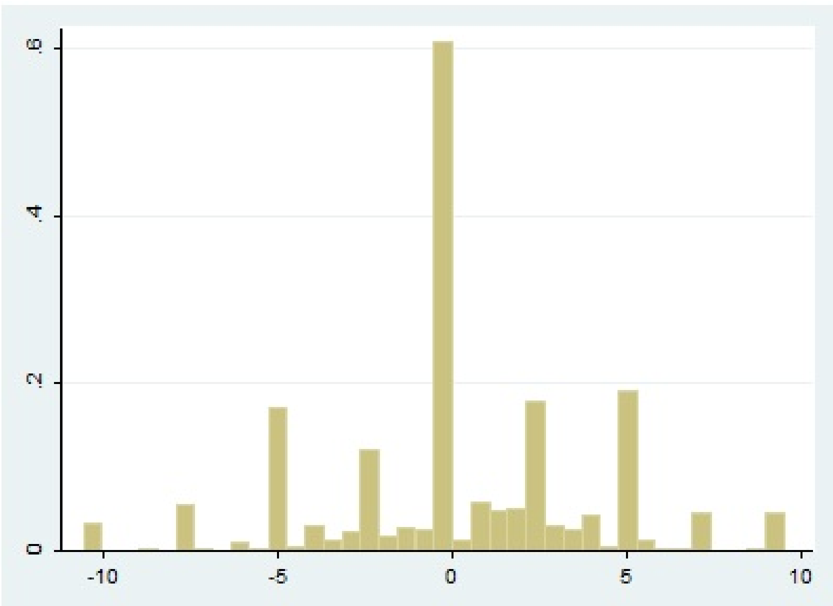

Figure D2 Self-Reported Change in House Prices

Source: DHS; *Notes:* The horizontal axis indicates the self-reported yearly percentage change in the price of the own house, while the vertical axis denotes the density. For the ease of exposition, only values between -10% and and 10 % are reported.

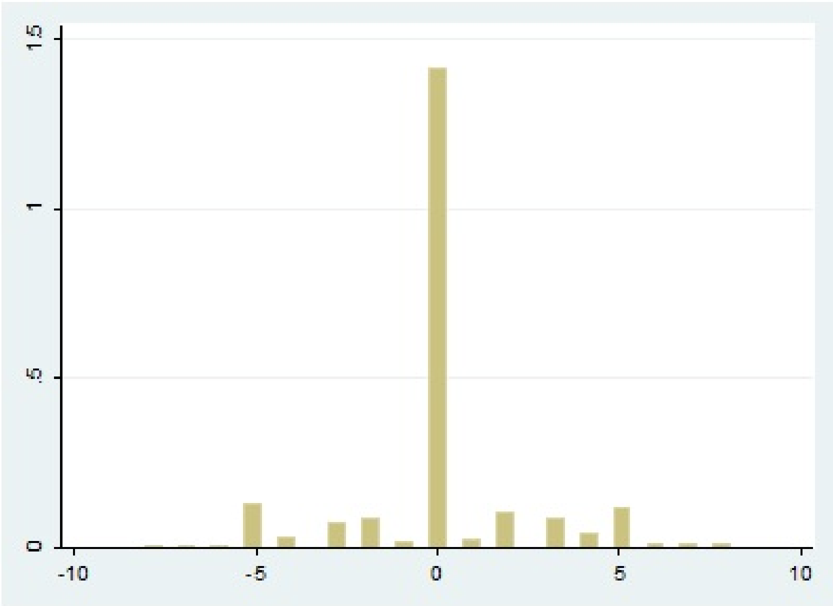

Figure D3 Expected Change in the Price of the Own House

Source: DHS; *Notes:* The horizontal axis indicates the expected percentage change in the price of the own house, while the vertical axis denotes the density. For the ease of exposition, only values between -10% and and 10 % are reported.

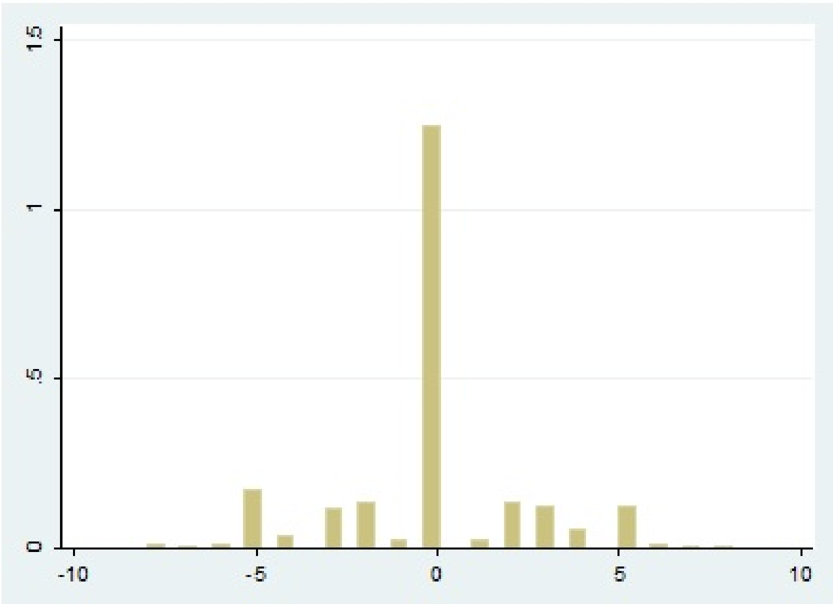

Figure D4 Expected Change in the Average House Market Price

Source: DHS; *Notes:* The horizontal axis indicates the expected percentage change in the average house market price, while the vertical axis denotes the density. For the ease of exposition, only values between -10% and and 10 % are reported.

Figures D1 to D4 show a clear rounding tendency towards particular values of each respective distribution. Below I provide an example derivation of the measurement error problem this implies. Let

$$\boldsymbol{y} = \boldsymbol{\iota}\beta_1 + \boldsymbol{x}^*\beta_2 + \boldsymbol{u}^*,$$

where $\boldsymbol{y} = \begin{pmatrix} \boldsymbol{y}_1 \\ \boldsymbol{y}_2 \\ \vdots \\ \boldsymbol{y}_n \end{pmatrix}$, $\boldsymbol{\iota} = \begin{pmatrix} \boldsymbol{\iota}_1 \\ \boldsymbol{\iota}_2 \\ \vdots \\ \boldsymbol{\iota}_n \end{pmatrix}$, $\boldsymbol{x}^* = \begin{pmatrix} \boldsymbol{x}_1^* \\ \boldsymbol{x}_2^* \\ \vdots \\ \boldsymbol{x}_n^* \end{pmatrix}$, $\boldsymbol{u}^* = \begin{pmatrix} \boldsymbol{u}_1^* \\ \boldsymbol{u}_2^* \\ \vdots \\ \boldsymbol{u}_n^* \end{pmatrix}$, and $\boldsymbol{y}_i$, $\boldsymbol{\iota}_i$, $\boldsymbol{x}_i^*$ and $\boldsymbol{u}_i^*$ are $T \times 1$ vectors. $\boldsymbol{x}^*$ is unobserved, instead we observe

$$\boldsymbol{x} = \boldsymbol{x}^* + \boldsymbol{\epsilon}.$$

I assume $\boldsymbol{u}^* \sim (\boldsymbol{0}, \boldsymbol{\Sigma}_u)$ and $\boldsymbol{\epsilon} \sim (\boldsymbol{0}, \boldsymbol{\Sigma}_\epsilon)$. Furthermore, I assume that $\text{Cov}(\boldsymbol{u}^*, \boldsymbol{x}^*) = \boldsymbol{0}$, $\text{Cov}(\boldsymbol{u}^*, \boldsymbol{\epsilon}) = \boldsymbol{0}$ and $\text{Cov}(\boldsymbol{x}^*, \boldsymbol{\epsilon}) = \boldsymbol{\gamma}$. In terms of the observations, the model can be formulated as

$$\boldsymbol{y} = \boldsymbol{\iota}\beta_1 + \boldsymbol{x}\beta_2 + \boldsymbol{u},$$

where

$$\boldsymbol{u} = \boldsymbol{u}^* - \boldsymbol{\epsilon}\beta_2.$$

So we have

$$E(\boldsymbol{u}|\boldsymbol{x}) = E(\boldsymbol{u}^* - \boldsymbol{\epsilon}\beta_2|\boldsymbol{x}^* + \boldsymbol{\epsilon}) = E(-\boldsymbol{\epsilon}\beta_2|\boldsymbol{x}^*) - \boldsymbol{\epsilon}\beta_2,$$

and

$$\begin{aligned}
\text{Cov}(\boldsymbol{u}, \boldsymbol{x}) &= \text{Cov}(\boldsymbol{u}^* - \boldsymbol{\epsilon}\beta_2, \boldsymbol{x}^* + \boldsymbol{\epsilon}) \\
&= E\left[(\boldsymbol{u}^* - \boldsymbol{\epsilon}\beta_2 - E\left(\boldsymbol{u}^* - \boldsymbol{\epsilon}\beta_2\right))\left(\boldsymbol{x}^* + \boldsymbol{\epsilon} - E\left(\boldsymbol{x}^* + \boldsymbol{\epsilon}\right)\right)'\right] \\
&= E\left[(\boldsymbol{u}^* - E(\boldsymbol{u}) - \boldsymbol{\epsilon}\beta_2 + E(\boldsymbol{\epsilon}\beta_2))(\boldsymbol{x}^* - E(\boldsymbol{x}^*) + \boldsymbol{\epsilon} - E(\boldsymbol{\epsilon}))\right] \\
&= \text{Cov}(\boldsymbol{u}^*, \boldsymbol{x}^*) + \text{Cov}(\boldsymbol{u}^*, \boldsymbol{\epsilon}) - \text{Cov}(\boldsymbol{\epsilon}\beta_2, \boldsymbol{x}^*) - \text{Cov}(\boldsymbol{\epsilon}\beta_2, \boldsymbol{\epsilon}) \\
&= -\beta_2(\boldsymbol{\gamma} + \Sigma_{\boldsymbol{\epsilon}}).
\end{aligned}$$

Therefore, the explanatory variable and the disturbances are correlated, which implies that the estimate of β_2 will be inconsistent. However, note that due to its non-classical nature, implied by the correlation between $\boldsymbol{x}^*$ and $\boldsymbol{\epsilon}$, the measurement error does not lead to the usual attenuation bias result. The direction of the bias will be determined by the sign of the correlation between $\boldsymbol{x}^*$ and $\boldsymbol{\epsilon}$.

Appendix E: Model (Extended Version)

E1 Introduction

In this appendix I present an extended and more detailed version of the model in Section 2 of this paper. This appendix is structured as follows. In the next section I introduce and explain a basic four period life-cycle model without neither income nor lifetime uncertainty. In the third and fourth sections I study the optimal life-cycle profile of a homeowner and of a renter respectively. In section fifth I study the effects of an unexpected decline in house prices.

E2 Life-Cycle Model Without Housing

The results I arrive to in this section are standard and are really close to the ones found in Deaton (1992) and Attanasio and Brugiavini (2003). Nevertheless, this section is relevant since it lays out the basis for the introduction of housing. The model with housing appears as a special case of the basic model without housing.

Assume that the household lives for four periods, which can be roughly identified with the different stages of the life-cycle. Furthermore, assume that there is neither lifetime nor income uncertainty and that there are no liquidity constraints and no bequest motive. The non-consolidated budget constraint for each period can be written as

$$S_{t-1}(1+r) + Y_t = C_t + S_t, \tag{E.1}$$

where C_t and Y_t are the flow of consumption and income in period t, S_t is the stock of savings at the end of period t and r is the interest rate, which, for simplicity, I assume to be constant over time.[24] Furthermore, I assume the household is born without assets, there is no bequest motive, and credit markets do not allow the household to die indebted. These assumptions imply $S_0 = S_4 = 0$.

At the beginning of period one, the household maximizes the CRRA utility function

$$U(C_t^1) = \sum_{t=1}^{4} \frac{1}{(1+\rho)^{t-1}} \frac{(C_t^1)^{1-\gamma}}{1-\gamma}, \tag{E.2}$$

where C_t^1 stands for consumption at time t as planned in period one,[25] γ stands for the level of relative risk aversion and ρ is the rate of time preference, subject to the consolidated lifetime budget constraint given by

$$\sum_{t=1}^{4} \frac{Y_t}{(1+r)^{t-1}} = \sum_{t=1}^{4} \frac{C_t^1}{(1+r)^{t-1}}. \tag{E.3}$$

The first order conditions yield the usual Euler equation

$$\left(\frac{C_{t+1}^1}{C_t^1}\right)^{\gamma} = \frac{1+r}{1+\rho}, \tag{E.4}$$

[24] Stock variables, like savings, are considered at the end of every period. All quantities are given in real terms.

[25] In what follows C_t^τ stands for consumption in period t as planned in period τ, while C_t stands for realized consumption in period t.

which, combined with (E.3), gives the following closed form solutions for consumption corresponding to periods one to four

$$C_1^1 = \frac{\sum_{t=1}^{4} \frac{Y_t}{(1+r)^{t-1}}}{1 + \left(\frac{1+r}{1+\rho}\right)^{\frac{1}{\gamma}} \frac{1}{(1+r)} + \left(\frac{1+r}{1+\rho}\right)^{\frac{2}{\gamma}} \frac{1}{(1+r)^2} + \left(\frac{1+r}{1+\rho}\right)^{\frac{3}{\gamma}} \frac{1}{(1+r)^3}} = \frac{\Omega}{\Lambda_1},$$

$$C_2^1 = \frac{\sum_{t=1}^{4} \frac{Y_t}{(1+r)^{t-1}}}{\left(\frac{1+\rho}{1+r}\right)^{\frac{1}{\gamma}} + \frac{1}{(1+r)} + \left(\frac{1+r}{1+\rho}\right)^{\frac{1}{\gamma}} \frac{1}{(1+r)^2} + \left(\frac{1+r}{1+\rho}\right)^{\frac{2}{\gamma}} \frac{1}{(1+r)^3}} = \frac{\Omega}{\Lambda_2},$$

$$C_3^1 = \frac{\sum_{t=1}^{4} \frac{Y_t}{(1+r)^{t-1}}}{\left(\frac{1+\rho}{1+r}\right)^{\frac{2}{\gamma}} + \left(\frac{1+\rho}{1+r}\right)^{\frac{1}{\gamma}} \frac{1}{(1+r)} + \frac{1}{(1+r)^2} + \left(\frac{1+r}{1+\rho}\right)^{\frac{1}{\gamma}} \frac{1}{(1+r)^3}} = \frac{\Omega}{\Lambda_3},$$

and

$$C_4^1 = \frac{\sum_{t=1}^{4} \frac{Y_t}{(1+r)^{t-1}}}{\left(\frac{1+\rho}{1+r}\right)^{\frac{3}{\gamma}} + \left(\frac{1+\rho}{1+r}\right)^{\frac{2}{\gamma}} \frac{1}{(1+r)} + \left(\frac{1+\rho}{1+r}\right)^{\frac{1}{\gamma}} \frac{1}{(1+r)^2} + \frac{1}{(1+r)^3}} = \frac{\Omega}{\Lambda_4},$$

where Ω stands for the discounted value of lifetime income evaluated at period one and the Λs are the factors that distribute income among all the periods when consumption is planned at period one.[26] The closed form solution for each period's savings can be found by plugging the above expressions for consumption into the non-consolidated budget constraint (E.1), which yields the expression for the stock of savings at the end of period t as planned in period one, given by

$$S_t^1 = S_{t-1}^1(1+r) + Y_t - C_t^1,$$

where S_t^1 is the stock of savings at the end period t as planned in period one. This expression for savings holds for periods one to three since at the end of period four the household plans to have zero savings, *i.e.* $S_4^1 = 0$.

E3 Life-Cycle Model With Housing: The Case of a Buyer

In this section I consider the case of a household that owns the house it occupies. To buy a house in the Netherlands there is no downpayment required. The only requirement is that the income level of the household is high enough to cover the regular mortgage payments. Therefore, since there is previous income required, I consider the house is purchased at the start of the second period, hence the household is a renter in the first period. Because there is no bequest motive, the house is sold at the beginning of the last period. Therefore, in the last period, the household

[26] Note that id $\rho = r$ consumption is the same in all periods.

is again a renter. For simplicity, I do not consider the possibility of selling the house in periods two and three.

I start by writing the non-consolidated budget constraint of a homeowner for each one of the four periods. Given that the homeowner buys the house in the second period and sells it in the fourth (in both cases at the beginning of the period), and that the mortgage schedule needs to be satisfied, the non-consolidated budget constraints of a buyer for each one of the four are given by

$$Y_1 = C_1 + S_1 + K_1,$$

$$S_1(1+r) + Y_2 + (1-r^M)M = C_2 + S_2 + \alpha_2 H,$$

$$S_2(1+r) + Y_3 = C_3 + S_3 + M(1+r^M),$$

and

$$S_3(1+r) + Y_4 + \alpha_4 H(1-\phi) = C_4 + K_4,$$

respectively, where H is (constant) housing, α_t is the real price of housing, ϕ is the transaction cost related to selling the house, M is the borrowed amount in period two to pay for the house, r^M is the interest rate on the mortgage and K_t is the rental price. The αs are the ratio of the price of housing over the general price level (housing excluded).

The rate of change in house prices is given by μ_t. If μ_t is equal to general inflation, the real value of the house is constant. I assume constant general price level, hence it holds that $\alpha_t = \alpha_{t-1}(1+\mu_t)$. The household borrows in period two an amount M, which uses to afford the 100 % of the house price, which is $\alpha_2 H$. Therefore, $M = \alpha_2 H$ and both M and $\alpha_2 H$ cancel each other out in the non-consolidated budget constraint corresponding to the second period. This amount is repaid at the end of period three, while mortgage interests are paid both in period two and period three. As mentioned above, the household is a renter in the first and last periods. Therefore, in each of these periods it pays the rental price $K_t = \kappa + \delta\alpha_t H$, where κ is a constant factor and δ is the effect of the house value on the rental price. If $\delta = 0$ the rental price is independent of the home value. Like in the second section above, it holds again that $S_0 = S_4 = 0$.

I assume that there is uncertainty regarding the value of μ_t. In turn, this implies uncertainty regarding future house and rental prices. I assume the expected value of μ_t is positive and constant, which means the household expects a constant increase in house prices over time. Taking these assumptions into account, the consolidated budget constraint for a homeowner that sets an optimal plan for consumption and savings at the beginning of period one can be written as

$$\varOmega + E_1 \frac{\alpha_4 H(1-\phi)}{(1+r)^3} = \sum_{t=1}^{4} \frac{C_t^1}{(1+r)^{t-1}} + K_1 + E_1 \left(\frac{Mr^M}{(1+r)} + \frac{M(1+r^M)}{(1+r)^2} + \frac{K_4}{(1+r)^3} \right), \quad \text{(E.5)}$$

where the expectations operator appears due to the uncertainty in μ_t. The second term on the left hand side of (E.5) denotes the amount the household is expecting to receive when the house is sold at the beginning of the fourth period. The last term on the right hand side, denotes expected future housing costs. The rental price in the first period is excluded from the expectation since it is already known in the planning period. Following Campbell and Cocco (2007), I define the following utility function featuring separability between consumption and housing

$$U(C_t^1, H) = \sum_{t=1}^{4} \frac{1}{(1+\rho)^{t-1}} \left(\frac{(C^1)_t^{1-\gamma}}{1-\gamma} + \theta \frac{(H(1+\lambda))^{1-\gamma}}{1-\gamma} \right), \tag{E.6}$$

where θ denotes the preference for housing and λ represents the utility gain from owning the occupied house. This implies $\lambda = 0$ for a renter and $\lambda \geq 0$ for an owner. In the latter case, the value of λ depends on the household preference for owning. Note that (E.6) is the same CRRA type of function as (E.2) but with housing included.

Due to the separability feature, the marginal utility of consumption is not affected by housing. Therefore, choosing consumption to maximize utility subject to the budget constraint yields the same Euler equation as given by Equation (E.4). This simplifies the matter since it allows studying changes in the value of housing solely as an income effect. Combining Equation (E.4) with the budget constraint given by Equation (E.5) I find the closed form solution for consumption given by

$$\begin{aligned} C_t^1 &= \frac{\Omega}{\Lambda_t} + \frac{1}{\Lambda_t} E_1 \left(\frac{\alpha_4 H(1-\phi)}{(1+r)^3} - K_1 - \frac{M r^M}{(1+r)} - \frac{M(1+r^M)}{(1+r)^2} - \frac{K_4}{(1+r)^3} \right) \\ &= \frac{\Omega + E_1 \Xi}{\Lambda_t}, \end{aligned}$$

where Ξ is what I call the owning factor and represents the share of lifetime income derived from housing as evaluated in period one. The above result holds for all periods from one to four. Note that K_1 can be taken out of the expectation and that for period one realized consumption is equal to planned consumption. The owning factor is the only change with respect to the closed form solutions for consumption found in the case without housing. Any change in the owning factor that is known in the planning period will be distributed among the four periods according to the Λ_t factors.

Once again, the solution for savings can be found by using the non-consolidated budget constraint for every period. For each period, planned savings is thus be given by

$$S_1 = Y_1 - C_1 - K_1,$$

$$S_2^1 = S_1(1+r) + Y_2 - C_2^1 - E_1 M r^M,$$

$$S_3^1 = S_2^1(1+r) + Y_3 - C_3^1 - E_1 M(1+r^M),$$

and $S_4^1 = 0$. It becomes clear now that unexpected changes in the value of housing will have an effect on consumption and saving behaviour. I leave the analysis of the consequences of a change in the value of housing for the fifth section of this appendix.

E4 Life-Cycle Model With Housing: The Case of a Renter

In this section I consider the case of a household that rents the house it occupies. Just like in the case of an owner, I start by writing the non-consolidated budget constraints for each period, which, in generic form, are given by

$$S_{t-1}(1+r) + Y_t = C_t + S_t + K_t,$$

where once more we have $S_0 = S_4 = 0$ and $K_t = \kappa + \delta\alpha_t H$. The consolidated budget constraint for a household that solves the maximization problem at the beginning of the first period can be written as

$$\Omega = \sum_{t=1}^{4} \frac{C_t^1 + E_1 K_t}{(1+r)^{t-1}}. \tag{E.7}$$

Employing the same CRRA utility function as the one given in Equation (E.6) and setting $\lambda = 0$, I arrive again to the Euler equation as given by Equation (E.4). Combining the Euler equation and the consolidated budget constraint given by (E.7), I find the closed form solutions for consumption, which are given by

$$C_t^1 = \frac{\Omega}{\Lambda_t} - \frac{1}{\Lambda_t} E_1 \sum_{t=1}^{4} \frac{K_t}{(1+r)^{t-1}} = \frac{\Omega - E_1 \Psi}{\Lambda_t},$$

where Ψ is what I call the renting factor which includes lifetime rental payments as evaluated in period one. Note that K_1 can be taken out of the expectation and that in period one planned consumption is equal to realized consumption. Just like in the case of the owning factor, any change in the renting factor that is known in the planning period will be distributed among the four periods according to the Λ_t factors. Again the solution for savings can be found by using the non-consolidated budget constraint for every period, which yields

$$S_t^1 = S_{t-1}^1(1+r) + Y_t - C_t^1 - K_t$$

for periods one to three. Again $S_4^1 = 0$ due to the lack of a bequest motive.

E5 The Effect of Housing Price Declines on Consumption and Savings

If the expectation about the rate of change in house prices, μ_t, is satisfied in every period, realized consumption and savings are equal to the plan set in period one, and the house is sold in period four at the expected price. In this section, I consider an unexpected shift in μ_t, from positive to negative. This implies a negative surprise for the household, since the household expects μ_t to be positive and constant over time. The surprise does not affect the expected value of μ_t. Therefore, the household expects that the rate of change in house prices will come back to its previous level the next period and stay constant from then onwards. The information about the actual value of μ_t becomes available at the beginning of each period.

I study the reaction in terms of consumption and savings when the drop in μ_t takes place in either the second, third or fourth period. Therefore I consider three different scenarios for a particular household. It is clear that if the change takes place in the first period the new information will be automatically incorporated in the decision determining the optimal plan. However, if the unexpected change in μ_t takes place between the second and fourth period, the household will replan consumption and savings of that period and of those that are still to come.

Therefore, realized consumption will differ from the plan set in period one. In what follows I show how an unexpected change in α_t implied by a negative μ_t has a contemporaneous effect on savings and consumption, the size of which is contingent on the stage of the life-cycle.

I start by focusing on the case of the buyer. If the change takes place in the second period, *i.e.* $\mu_2 < 0$, I assume that it happens right after the home purchase, which implies that the mortgage payment will not be affected by the drop in house prices .[27] Therefore, reoptimization implies choosing C_2, C_3 and C_4 to maximize the utility function

$$U(C_t^2) = \sum_{t=2}^{4} \frac{1}{(1+\rho)^{t-2}} \left(\frac{(C_t^2)^{1-\gamma}}{1-\gamma} + \theta \frac{(H(1+\lambda))^{1-\gamma}}{1-\gamma} \right),$$

subject to the updated budget constraint

$$\Omega^2 + E_2 \frac{\alpha_4 H(1-\phi)}{(1+r)^2} = \sum_{t=2}^{4} \frac{C_t^2}{(1+r)^{t-2}} + Mr^M + E_2 \left(\frac{M(1+r^M)}{(1+r)} + \frac{K_4}{(1+r)^2} \right), \tag{E.8}$$

where

$$\Omega^2 = \sum_{t=2}^{4} \frac{Y_t}{(1+r)^{t-2}}.$$

Note that $E_2\alpha_4 = \alpha_1(1+\mu_2)E_2(1+\mu_3)(1+\mu_4) < E_1\alpha_4 = E_1\alpha_1(1+\mu_2)(1+\mu_3)(1+\mu_4)$, since the realized value of μ_2 is lower than was expected in period one. Therefore, the household is negatively surprised and now expects to sell the house in the last period for a lower price than it was expected in period one. Since the decline in house prices is not taken into account in the price paid for the newly acquired house, the mortgage payments remain the same. Combining the Euler equation resulting from the maximization problem with the budget constraint in (E.8) yields the closed form solution

$$C_t^2 = \frac{\Omega^2}{\Lambda_t^2} + \frac{1}{\Lambda_t^2} E_2 \left(\frac{\alpha_4 H(1-\phi)}{(1+r)^2} - Mr^M - \frac{M(1+r^M)}{(1+r)} - \frac{K_4}{(1+r)^2} \right) = \frac{\Omega^2 + E_2 \Xi^2}{\Lambda_t^2},$$

where

$$\Lambda_2^2 = 1 + \left(\frac{1+r}{1+\rho} \right)^{\frac{1}{\gamma}} \frac{1}{(1+r)} + \left(\frac{1+r}{1+\rho} \right)^{\frac{2}{\gamma}} \frac{1}{(1+r)^2},$$

$$\Lambda_3^2 = \left(\frac{1+\rho}{1+r} \right)^{\frac{1}{\gamma}} + \frac{1}{(1+r)} + \left(\frac{1+r}{1+\rho} \right)^{\frac{1}{\gamma}} \frac{1}{(1+r)^2},$$

and

$$\Lambda_4^2 = \left(\frac{1+\rho}{1+r} \right)^{\frac{2}{\gamma}} + \left(\frac{1+\rho}{1+r} \right)^{\frac{1}{\gamma}} \frac{1}{(1+r)} + \frac{1}{(1+r)^2}.$$

Note that that all mortgage payments are already known in the second period since $M = \alpha_2 H$ and thus they can be taken out of the expectation. In addition, for the second period planned consumption is equal to realized consumption.

Assuming that the loss implied by the decrease in the expected value of housing is larger

[27] This assumption is grounded on the fact that in this section I want to study the effect of house price declines for the case of homeowners, and not soon-to-be homeowners.

than the benefit implied by the expected decrease in the fourth period rental price, the period two decline in house prices reduces lifetime income and thus implies, ceteris paribus, a reduction in consumption. However, the decline in consumption is smoothed over periods two, three and four. Note that the effect on consumption would be ambiguous if mortgage payments were allowed to change as well.

To study the contemporaneous effect of the house price decline, I define realized consumption in period two as a function of the plan set in period one and a forecast error, *i.e.*

$$C_2 = C_2^1 + \eta_2,$$

where η_2 is the forecast error denoting the difference between realized and planned consumption in period two. The forecast error appears directly as a consequence of the unexpected change in house prices. Since I am considering a decline in house prices, the forecast error is negative, which means that realized consumption is smaller than planned consumption.

If the household is in the third stage of the life-cycle when the change in μ_t takes place, reoptimization will imply choosing C_3 and C_4 to maximize utility subject to the updated budget constraint

$$\Omega^3 + E_3 \frac{\alpha_4 H(1-\phi)}{(1+r)} = \sum_{t=3}^{4} \frac{C_t^3}{(1+r)^{t-3}} + M(1+r^M) + E_3 \frac{K_4}{(1+r)}, \tag{E.9}$$

where

$$\Omega^3 = \sum_{t=3}^{4} \frac{Y_t}{(1+r)^{t-3}}.$$

The surprise in μ_3 represents now exactly the same change in lifetime income as when the surprise was considered in the second period of the life-cycle.[28] That is the case because of three reasons: first, I am always considering the same size for the unexpected change in μ_t; second, $E_t\mu_t$ is constant and positive over time and, third, in the periods previous to a house price decline I assume the expectations about μ_t were satisfied. These assumptions provide the advantage of allowing the evaluation of exactly the same drop in lifetime income, but at different stages of the life-cycle.

Maximizing utility subject to the updated budget constraint given by (E.9) yields

$$C_t^3 = \frac{\Omega^3}{\Lambda_t^3} + \frac{1}{\Lambda_t^3} E_3 \left(\frac{\alpha_4 H(1-\phi)}{(1+r)} - M(1+r^M) - \frac{K_4}{(1+r)} \right) = \frac{\Omega^3 + E_3 \Xi^3}{\Lambda_t^3},$$

where

$$\Lambda_3^3 = 1 + \left(\frac{1+r}{1+\rho} \right)^{\frac{1}{\gamma}} \frac{1}{(1+r)},$$

and

$$\Lambda_4^3 = \left(\frac{1+\rho}{1+r} \right)^{\frac{1}{\gamma}} + \frac{1}{(1+r)}.$$

[28] That means $E_2\alpha_4$ takes the same value irrespective of whether the decline in house prices takes place in the second or third periods. Therefore, the household expects to sell the house for the same diminished value no matter when the decline in the price takes place.

Note that $M(1+r^M)$ could be taken out of the expectation and for period three planned consumption equals realized consumption. The household has now only two periods to smooth the shock implied by the drop in lifetime income. Therefore, the contemporaneous negative effect on consumption for a household in the third stage of the life-cycle is greater than for a household that is on the second stage of the life-cycle. Once again the contemporaneous effect of the decline in house prices can be depicted by writing realized consumption as a function of the plan set in period one plus a forecast error, *i.e.*

$$C_3 = C_3^1 + \eta_3.$$

If the household is in the fourth stage of the life-cycle when the change in μ_t takes place, reoptimization will imply choosing only C_4 to maximize utility subject to the updated budget constraint

$$Y_4 + \alpha_4 H(1-\phi) = C_4 + K_4,$$

which directly yields

$$C_4 = Y_4 + \alpha_4 H(1-\phi) - K_4 = Y_4 + \Xi^4,$$

where there are no expectations and planned consumption is equal to realized consumption. Now the full shock to lifetime income is absorbed by a reduction in consumption in period four. Therefore, the contemporaneous shock to consumption is the greatest when the household is at the last stage of the life-cycle. This result make sense, since the longer is the planning horizon when the shock occurs the more periods there are to absorb it and the smallest is the contemporaneous effect on consumption. Once again, the contemporaneous effect of the decline in house prices can be depicted by writing realized consumption as

$$C_4 = C_4^1 + \eta_4.$$

To find the effect on savings, I use the expressions that derive from the unconsolidated budget constraints, which are given in the third section of this appendix. As it is shown there, for a given level of income and mortgage payments, savings will change by the same amount but in the opposite direction as consumption. By the same result given for consumption, the savings increase will be higher the later in life the shock occurs, with the exception of the fourth period, for which it still holds that $S_4 = 0$ due to the absence of a bequest motive. Just like I have done for consumption, the contemporaneous effect of a house price decline on savings can be studied by expressing realized savings as planned savings plus a forecast error. The contemporaneous effect on savings of a change in house prices in period two and three is then given by

$$S_2 = S_1(1+r) + Y_2 - C_2^1 - Mr^M - \eta_2$$

and

$$S_3 = S_2(1+r) + Y_3 - C_3^1 - M(1+r^M) - \eta_3$$

respectively. Note that plugging in a negative surprise in lifetime income implied by a decline in house prices, *i.e.* $\eta_2 < 0$ and $\eta_3 < 0$ respectively, will imply an increase in realized savings above what was planned in period one.

Regarding the effect of the above considered housing shock for a household who rents the place it occupies, it can be easily seen that it will imply a decline on the rental price. That is because I have considered the rental price as a function of the value of the house. Therefore, a decline in the real vaule of the house implies a decline in the rental price as long as $\delta > 0$. This decline would imply an increase in lifetime income and thus an increase in consumption and a decrease in savings. However, this does not seem very realistic, especially for the Dutch case, where the rental market is highly regulated and, according to CBS, almost 50% of rental homes are part of social housing programs and thus rental prices are rather sticky.

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